

MARKET SIZE AND DEMAND FOR MARIJUANA IN COLORADO 2017 MARKET UPDATE

PREPARED FOR THE COLORADO DEPARTMENT OF REVENUE





Marijuana Policy Group LLC (MPG) (www.mjpolicygroup.com) is a consulting and research firm focused on legal cannabis markets. MPG helps governments design best-practice regulations and monitoring programs to meet public-sector goals. Private operators and investors rely upon MPG insights to excel in emerging legal markets for cannabis and hemp products. MPG was formed in 2014 by consultants and university researchers in Denver, Colorado.

This report was commissioned by the Colorado Department of Revenue, Marijuana Enforcement Division, and was conducted as a joint effort by experts from MPG and the University of Colorado Boulder, Leeds School of Business, Business Research Division. This report reflects the independent analysis of the study team.

Release: August 2018

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The authors are grateful for suggestions and assistance from Michael Hartman, Jim Burack, Shannon Gray, Kyle Lambert, Philip Martin, and Eric Hurley. Any omissions or errors are the sole responsibility of the report team.

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GLOSSARY

- **Adult use marijuana.** Marijuana that is grown and sold pursuant to the Retail Code and includes seeds and immature Plants. Unless the context otherwise requires, Adult use marijuana concentrate is considered adult use marijuana and is included in the term. The terms “retail” and “recreational” were often used in this context previously.
- **Cannabinoid.** Any of the chemical compounds that are the active principles of marijuana. Cannabinoids include THC, THCa, CBD, CBDa, CBN, and other naturally occurring compounds.
- **Caregiver.** Colorado Revised Statute 25-1.5-106 defines four types of caregivers for medical marijuana patients, the services they provide, and legal requirements: (1) Cultivating- grows marijuana on behalf of patients; (2) Transporting- transports marijuana for homebound or minor patients; (3) Parents of a minor patient- Parents of a patient under age 18; and (4) Advising- Advises patients on the medicinal use of marijuana. All cultivating and transporting caregivers are required to register.
- **Concentrate.** Refers to any product which refines marijuana flower into something more clean and potent. This umbrella term includes any type of hash, solventless (kief), as well as any hash oils (BHO, CO2 oil, shatter, wax, etc.) and indicates that these products are a concentrated form of cannabis, carrying a higher potency.
- **Edible.** Any adult use or medical marijuana product for which the intended use is oral consumption, including but not limited to, any type of food, drink, or pill.
- **Flower equivalent.** A measure developed specifically for this study that converts non- flower consumption or production into weight-based units of flower. This method allows regulators to properly compare supply, demand, potency, and pricing across different product types.
- **Infused product.** A product infused with marijuana that is intended for use or consumption other than by smoking, including but not limited to edible product, ointments, and tinctures.
- **Inventory tracking system.** The required seed-to-sale tracking system that tracks adult use and medical marijuana from either the seed or immature plant stage until the marijuana, marijuana concentrate, or marijuana product is sold to a customer at an adult use marijuana store or medical marijuana center.
- **Licensee or license holder.** Any individual licensed pursuant to the Colorado Retail Code or Medical Code.
- **Marijuana demand.** Marijuana demand is defined as the annual amount of marijuana sold in regulated adult use stores and medical centers expressed in weight.
- **Marijuana flower.** The flowering buds of the female marijuana plant that are harvested and cured for sale to processors, adult use stores or medical centers.
- **Marijuana supply.** The annual amount of marijuana flower and trim harvested expressed in weight (metric tons).
- **Medical marijuana.** Marijuana that is grown and sold pursuant to the Medical Code and includes seeds and immature Plants. Unless the context otherwise requires, Medical Marijuana Concentrate is considered Medical Marijuana and is included in the term.
- **Regulated marijuana.** Adult use and medical marijuana that is under the regulatory oversight of the Colorado Department of Revenue’s Marijuana Enforcement Division.
- **THC.** Delta-9-tetrahydrocannabinol, the main psychoactive compound in marijuana.
- **Trim (Shake).** After harvest, the marijuana plant is generally trimmed of its leaf matter, leaving behind only the buds. Trim refers to the leftover leaves, which can be used for making concentrates and infused products.

EXECUTIVE SUMMARY

Shortly after the legalization of adult use marijuana in Colorado in 2014, the Colorado Department of Revenue's Marijuana Enforcement Division (MED) requested an estimate of the market size, in metric tons, for marijuana for medical and adult use consumers. It was also noted that it would be helpful to revisit market size and demand over time as more official market data are collected through the state's inventory tracking system. This market update is the culmination of those efforts. It provides an updated view and assessment of Colorado's regulated marijuana markets through 2017, and it improves upon the original 2014 market study methods.

This report relies on marijuana inventory tracking data, provided by the state in accordance to the terms of an interagency agreement, and contains several new findings that provide insights into the nation's most mature regulated marijuana market. This information will be valuable as the state evaluates its early regulatory outcomes. Through careful inventory tracking, data analysis, and program evaluation, regulators can ensure a well-organized market as envisioned by voters who approved Amendment 64 in 2012.

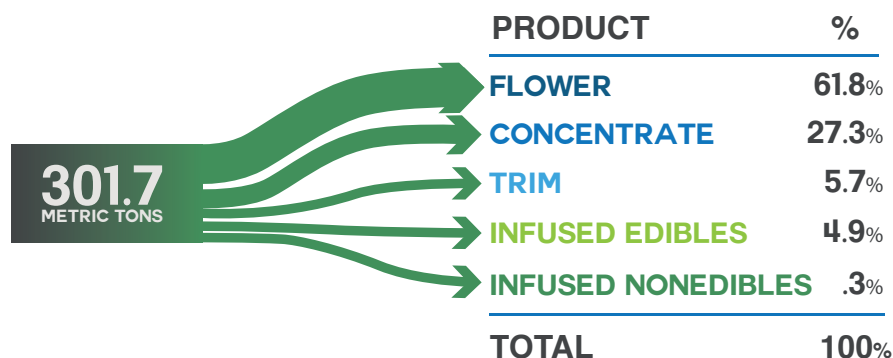
Key topics examined in the report are summarized here and presented in detail within the main report.

- Flower Equivalent Measures.** Smoking marijuana flower is still the predominant consumption method in the regulated market, but there is a clear trend toward consumption of non-flower products, such as concentrates and edibles. The study team has developed a new measure, called "Flower Equivalent", to account for non-flower consumption.

This measure converts non-flower sales or production into weight-based units of flower. This method allows regulators to properly compare supply, demand, potency, and pricing across different product types. Flower equivalent is a tool that can help regulators to establish rules, measure demand quantity, and achieve regulatory objectives going forward.

The use of a stable constant—which the flower equivalent represents—will better inform officials about adjusting tax rates, plant allocations, and other regulatory parameters. For example, plant counts or canopy size can be adjusted to account for the supply of trim, which can improve regulatory accuracy (refer to page 6-7 more information).

Colorado Marijuana Demand, 2017 Actual Sales, Metric Tons of Flower Equivalent

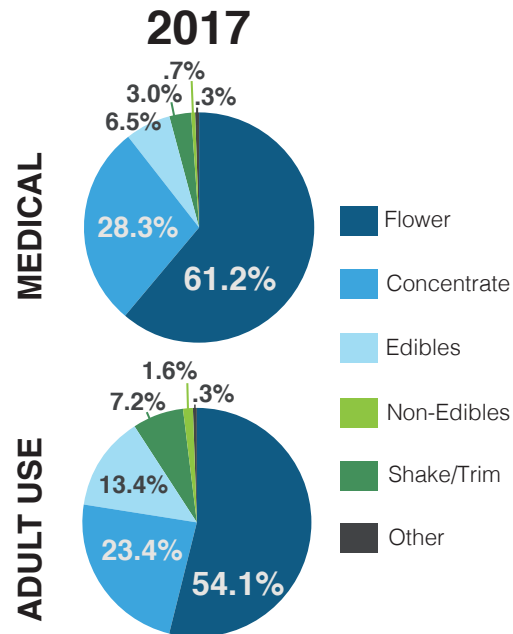


Source: Study team calculations and methods, using state sales data.

- Improved Licensee Compliance.** The trend over the last three years shows improved licensee compliance. Total contaminated, destroyed, or seized products as a percent of total production volume over time has declined from 9.2 percent in 2015, to 2.9 percent in 2016, and down to 1.9 percent in 2017. This measure indicates broad improvement in compliance, more accurate reporting, better internal controls, better use of the inventory tracking system by state and industry, and an effective regulatory and enforcement system (refer to page 9-10 more information).

- Market Trends.** Price trends within Colorado's adult use and medical markets continue to evolve as the marketplace matures; and as non-flower products gain market share compared to flower marijuana. Demand for flower marijuana products as a portion of overall sales has declined each year since the market opened in 2014. The study team has derived a new measure, called the "price per standard serving" of marijuana, to reflect how the price of a single serving of marijuana has declined relative to the price of each gram or unit. The price of marijuana flower is falling gradually, while the price for a "standard serving" of THC has declined more rapidly. It is unclear whether this is a long-term trend that leads to a "high THC/ low price" paradigm, or whether the market price will stabilize to suggest an equilibrium (refer to page 21-23 for more information).

Product Type Market Share by Value, 2017



Source: Study team calculations using state sales data.
 Note: "Other" sales includes immature plants, seeds and related products.

- Geographic Variation.** Observed prices are generally above average in mountain tourist regions but are highest in regions with a limited number of adult use store locations. This indicates that retail margins are larger in markets with limited competition than in tourism-based or in high-volume markets. Per capita sales are high in regions with large numbers of annual visitors, including border regions, which indicates that visitors account for a sizable portion of sales. Denver County, which is home to 13 percent of the Colorado population, accounted for nearly 34 percent of all marijuana sales in 2017. The broader Denver Metro Area (51 percent of the state population) combined for 54.9 percent of the state marijuana sales (refer to page 24 more information).

- Supply, Demand and Consumption.** For the purposes of this study, regulated marijuana supply is defined as the annual amount of marijuana flower and trim harvested expressed in weight (metric tons). Regulated marijuana demand is defined as the annual amount of marijuana sold in regulated adult use stores and medical centers expressed in weight. Consumption is the estimated amount of marijuana consumed by Colorado residents and tourists calculated using survey results.

In 2017, regulated cultivators in Colorado supplied 340.7 metric tons of flower equivalent to the market. Demand for regulated marijuana in 2017 is 301.7 metric tons of flower equivalent as calculated from actual sales of marijuana product. Companies held 32.6 metric tons of inventories and there was a 1.9 percent residual value. Several factors contribute to the residual value, including seizure and destruction of

marijuana; failure to meet quality assurance standards; losses in harvest, trimming and extraction processes; inventory shrinkage; and other factors. Refer to Section 2 (page 5) for a detailed discussion of supply/demand dynamics.

The study team estimates Colorado residents and tourists consumed 208.7 metric tons of flower equivalent in 2017, using standard consumption estimation techniques updated from the 2014 study.

A comparison of inventory tracking data and consumption estimates signals that Colorado's preexisting illicit marijuana market for residents and visitors has been fully absorbed into the regulated market. The 2017 results also highlight an evolution from the last study, conducted in 2014. In 2014, the study team estimated that the regulated market would capture about 65 percent of resident and tourist consumption.

For 2017, the results also suggest there is additional demand for Colorado marijuana that is not captured in standard resident and tourist consumption estimation techniques. This discrepancy between demand and consumption estimates can be caused by several factors including: at-home consumer inventory; legal in-state purchases that are consumed out of state; demand from the under-21 population; under-estimated demand or waste by visitors; and the inclusion of edible and concentrate products that were not fully considered in federal surveys. A full discussion of these factors is included in Section 2.

It is not surprising to observe a variance between supply, demand and consumption figures, because this is the first full-scale study to use official sales data that captures all product types and converts them to flower equivalent units, thus enabling comparison of total supply, demand and estimated consumption by residents and visitors. Stakeholders may wish to monitor these supply, demand and consumption factors going forward and to establish benchmarks or standards. Such benchmarking allows regulators, stakeholders, and policymakers to compare outcomes over time, and between different states. Colorado offers valuable insights as the most mature and evolved legal market in the U.S.

- **Plant Allocations and Utilization.** The authorized medical marijuana plant allocation in Colorado is driven by patients' physician recommendations regarding consumption amounts. The authorized adult use marijuana plant allocation is controlled through state issued licenses that determine the maximum plant count in a tiered system. At the end of 2017, medical marijuana cultivators were growing 322,800 plants, while permitted to grow up to 555,000 plants—an average utilization of 58 percent. In the adult use market, cultivators were growing 675,005 plants at the end of 2017, while permitted to grow up to 1,985,400—an average utilization of 34 percent. This suggests a saturated market, where producers are adjusting production to pricing and consumer demand (refer to page 29 more information).

- **Market Competitiveness and Consolidation.** An emerging topic of interest is the consolidation of cannabis companies in the United States and worldwide. To assess the degree of market concentration in Colorado, the study team applied economic measures of consolidation to Colorado's regulated marijuana market, and then compared those indicators to other markets. The study team found that while there exists some consolidation, the marijuana market is relatively more competitive (i.e., has more corporate entities vying to capture the same market share) than other markets such as beverages, food products, jewelry, and tobacco. Further consolidation may occur, but the economic and market implications related to this pattern remain to be seen (refer to page 32 more information).

The report is organized in four sections: 1. Overview; 2. Supply, Demand and Consumption; 3. Regulated Market Trends; and 4. Emerging Topics. The report also includes appendices that provide detail on resident and tourist consumption estimation and on market dynamics from 2016.

1 OVERVIEW

The Colorado Department of Revenue's Marijuana Enforcement Division (MED) occasionally commissions technical studies to highlight key aspects of the state's regulated market.¹ The MED provides this information to improve market transparency and to inform decision makers about the status of Colorado's marketplace. The report provides several key metrics to the MED and the public for the first time and highlights the use of the state inventory tracking database to evaluate regulatory performance. This report is part of the state's continuous efforts to monitor a comprehensive marijuana regulatory framework.

This report is the second edition of the *Market Size and Demand for Marijuana in Colorado* that was originally published in June 2014. This second edition is fundamentally different from the 2014 study, mainly because the results are based primarily upon official data from the state marijuana inventory tracking system (METRC), rather than estimations. This edition provides new views into the legal marketplace from a systemwide to a licensee perspective.²

In the past four years, the state has experienced major shifts in consumption patterns, supply patterns, and market balance. This report highlights some of the more important developments in Colorado's regulated marijuana markets over the past four years—as viewed from a regulatory perspective.

A deliberate focus of this report is on the past two years, 2016 and 2017, as the market has evolved since 2014. Important changes in state regulatory practices since 2014 include: allowing new, non-vertically integrated entities to enter the market; introducing testing requirements for several product types that were previously exempted; and changing tax regulations.

Primary themes in this report are:

- New methods in demand and supply estimation
- Systemwide supply, demand and consumption comparison
- Regulated marijuana market trends
 - Price trends
 - Potency trends
 - Price trends by serving
 - Licensee market share trends
- Market concentration and consolidation in Colorado
- Plant allocations and utilization rates

The rest of this report provides detailed assessments of the topics presented in the Overview.

Key Market Changes: 2014-2017

- Vertical integration not required for adult use cultivations starting October 2014.
 - Mandatory adult use marijuana potency testing began in July 2014.
 - Non-resident investment, known as a “permitted economic interest,” is allowed starting in January 2016.
 - Standardized edible serving amounts of 10 mg or 100 mg packages in October 2016.
 - Combined state retail sales tax rates for adult use marijuana increase from 12.9 percent to 15 percent in July August 2017.
-

¹ Please refer to the MED Statistics and Resources page for more information: <https://www.colorado.gov/pacific/enforcement/med-resources-and-statistics>

² The MED currently regulates parallel medical and adult use marijuana markets. In most instances, this report presents a merged view of both markets referred to as the “regulated” market, if not explicitly identified as the “adult use” or “medical” market.

2 SUPPLY, DEMAND AND CONSUMPTION

Section 2 presents a new approach to measure supply and demand, derived from the state inventory tracking system and using a new unit called “Flower Equivalent” quantity. The need for an updated method to account for non-flower product types became clear in early 2015, as demand for concentrates and edibles continued to grow. In 2015, non-flower products represented about 25 percent of total sales, and data through 2017 indicate non-flower product market share continued to increase, now comprising 37.7 percent of the regulated market.

A flower equivalent measure allows regulators to monitor the quantity or weight of sales, in addition to a measure of value, to observe product movements as closely as possible. This is necessary because marijuana is a Schedule 1 controlled substance in the Federal Controlled Substances Act, and unlike tobacco or alcohol, not all states have legalized adult use marijuana markets.

Section 2.1 describes the Flower Equivalent approach; Section 2.2 identifies market demand, supply and statewide product flows using inventory tracking data; Section 2.3 provides estimates of marijuana consumption using best practice estimation methods; and Section 2.4 compares results with actual demand to draw conclusions on the illicit market.

2.1 NEW QUANTITY ESTIMATION METHODS

A growing share of regulated marijuana sales are in marijuana flower alternatives, such as concentrates or edibles. In 2017, for example, more than one third (37.7 percent) of total sales were non-flower products, compared to 25.4 percent in 2015. The most popular alternatives are oil-filled vaporizer cartridges, wax/shatter concentrates, and infused edibles. Compared to the overall increase in marijuana sales of 51.6 percent from 2015 to 2017 (\$996 million to \$1.5 billion)³, concentrated product sales increased by 114 percent and infused edible sales increased by 67 percent over the same period. The increase in market share of concentrates and edibles requires a common unit of measure for the state to evaluate supply and demand factors.

Non-flower products require different amounts of marijuana plant material according to production method and have a different number of servings in each package depending on product type. The “Flower Equivalent” method translates infused and concentrated products into their flower-weight equivalent. Conversion factors were constructed by the study team to develop in-store sales limitations as part of the “Marijuana Equivalency in Portion and Dosage” commissioned by the MED in 2015.⁴ The process traces marijuana weight and potency through the concentrate and edible production process and matches inputs (marijuana plant material) with outputs (concentrates and infused products) actually produced.

This measure is used to adjust the actual demand calculation to convert demand that occurs in multiple product types into the same units as supply or harvests, which are denominated in grams (or tons) of marijuana flower and trim. This is also the same unit of measure used in resident and tourist consumption estimation.

Plant Material Equivalencies

To construct flower equivalent supply and demand, different product types are scaled together with their respective conversion units. The calculation also accounts for different loss ratios between input plant material and product outputs. A systemwide assessment must also account for the fact that marijuana shake and trim is used in various manufacturing processes. While flower is typically sold directly to customers, shake and trim is primarily used as an intermediate input. A smaller amount of shake and trim is sold directly to consumers, often as pre-rolled joints.

As non-flower products grow to represent a larger portion of the overall market, the role of marijuana

³ Colorado Department of Revenue, Marijuana Sales Reports. <https://www.colorado.gov/pacific/revenue/colorado-marijuana-sales-reports>

⁴ Marijuana Policy Group. (2015). “Marijuana Equivalency in Portion and Dosage.” https://www.colorado.gov/pacific/sites/default/files/MED%20Equivalency_Final%2008102015_1.pdf

trim is increasingly important as part of the supply-side plant yield. Using the plant trim increases yields per plant or per square foot of canopy. Consequently, the number of plants that are necessary to satisfy total demand is less than previously considered. Increases in potency or total cannabinoids in each plant and increased production efficiencies may also have the same effect.

As part of the 2015 marijuana equivalency study, interviews were conducted with edible manufacturers and with extraction specialists to determine different production processes for each product type. Average yields were established for flower or shake and trim as the primary input. This information was then combined with official production, yield, and potency testing data from the state inventory tracking system to determine input and output ratios for each broad product category.

Key Factors for Flower Equivalent Measures of Supply and Demand

- **Shake and trim as a THC source.** Many non-flower products can be produced using shake and trim. Shake is the industry term used to describe the small pieces of flower marijuana that have broken off the larger marijuana buds. Trim consists of the leftover leaves that are trimmed from the marijuana flower. For manufacturing purposes, shake and trim offer a more cost-effective input than flower and provide reasonable levels of THC for extraction.
- **Plant-material input price.** Similar to any business seeking to minimize production costs, infused product manufacturers will choose a least-cost combination of flower and trim as inputs to produce infused and concentrated extract marijuana-based products. Shake and trim is the preferred input because the price per unit of THC is less than flower. For example, the official average market rate (AMR) for trim at the end of 2017 was \$405 per pound and \$1,305 per pound of flower.⁵ Using the 2017 estimates of THC content for trim and flower, the wholesale price per milligram of THC from trim equals 0.52 cents. In contrast, the cost per milligram of THC from flower equals 1.7 cents. Thus, THC borne from marijuana flower in Colorado is 3.3 times more expensive than THC from trim.
- **Extraction yields.** Extraction yield is the ratio of input plant material needed to produce one gram of concentrated product. For example, it is commonly understood that about 7 grams of trim is needed to produce one gram of butane hash oil (BHO).⁶ However, these yields are different depending on the solvent used in extraction. Yields are always changing as production and refinement technology evolves.

During the production process for concentrates and infused products, some amount of plant material and THC dissipates. For example, THC is commonly infused into cookies, brownies, and other baked goods by first constructing cannabis-infused butter, where THC is extracted from plant material and is then reconstituted into THC-infused butter. This butter is combined with other confectionary inputs to provide a final edible product. However, some of the THC in the plant material dissipates in the process.

Marijuana consumption, demand and supply quantities are estimated using different methods.

Shake and Trim – Prices

The cost of shake and trim is much lower than flower when measured per milligram of THC. At the end of 2016, wholesale flower prices in the adult use market were more than three times the price of trim, with DOR-defined average market rates of \$1,816 per pound of flower and \$505 per pound of trim in the adult use market. Average market rates at the end of 2017 showed this trend had continued, with the adult use flower rate at \$1,305 per pound and adult use trim at \$405 per pound.

Shake and Trim – Potency

In previous years, the average potency of shake and trim was lower than flower (14.9 percent versus 16.6 percent in 2015). Current data indicate that the potency in both shake and trim (17.2 percent) and flower (19.6 percent) has increased noticeably. This increase in input product potency leads to higher THC yields following the extraction process.

⁵ Colorado Department of Revenue, Average Market Rate report. <https://www.colorado.gov/pacific/sites/default/files/AverageMarketRatesforPriorPeriods.pdf>

⁶ Marijuana Policy Group. (2015). "Marijuana Equivalency in Portion and Dosage." https://www.colorado.gov/pacific/sites/default/files/MED%20Equivalency_Final%2008102015_1.pdf

Consumption is based upon demographics, consumer responses to surveys, and upon pre-existing literature on use. In other words, it must be estimated. In contrast, legal marijuana supply and demand do not need to be estimated – the measures can be counted using official, verified data from the state’s inventory tracking system. In order to standardize different products back into grams of flower equivalent, the study team constructed a generalized equivalency approach. The general formula is written. This approach can be used to convert different products – such as edibles, concentrates, or processed flower, back into the weight of plant material needed to produce the product. The formula is below:

$$W_{it} = f(n, mg, \pi_t, \sigma_t, L, \phi_i)$$

Where each component is defined as follows:

- W_{it} is the equivalent weight of flower or trim needed as an input for each product type.
- The index “ i ” is the type of plant material (flower or trim).
- The index “ t ” denotes the type of non-flower product (wax, vaporizer cartridge, infused edible, infused non-edible, etc.) being considered.
- The function, $f(n, mg, \pi_t, \sigma_t, L, \phi_i)$, depends upon the following input parameters:
 - n is the number of units produced or sold. For example, n equals 2.7 million units in 2017 in the case of edible marijuana products for Colorado.
 - mg is the weight of the product, in milligrams or grams, of the product sold. For example, “wax” type concentrates are typically sold in units of 1 gram. Vaporizer cartridges are sold in units of 250 milligrams or 500 milligrams. For edibles, this weight is set to be the official THC weight itself (e.g., 10 or 100 milligrams).
 - π_t represents the potency of the product, as a percentage of the product weight, using official laboratory test data. If a concentrate batch test equals 65 percent, then 0.65 is used for π_t .
 - σ_t represents the share of total sales by product type, t . σ_t can be used to compute systemwide supply equivalencies, or it can be omitted from the formula, if only a specific product type is under consideration.
 - L is the loss rate between plant-based input THC and the output THC. The loss rate can vary between 20 percent for concentrates up to 40 percent for edibles, if more than one chemical transaction is enacted.
 - ϕ_i is the THC potency of the input material, based upon official test data. For example, average potency testing for flower in 2017 suggests potency during that year of 19.6 percent combined THC-A and THC. Trim potencies are 17.2 percent THC, on average, in 2017.

Formula estimates for legal jurisdictions outside of Colorado may differ based upon relative potencies, plant yields, and other factors that affect production.

2.2 DEMAND, SUPPLY AND STATE-WIDE PRODUCT FLOWS

The study team used Colorado's inventory tracking system to account for regulated cultivation, production, and sales in a detailed manner.

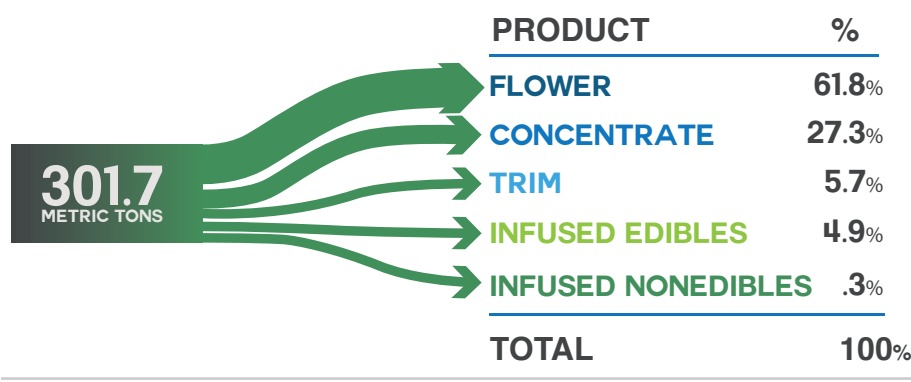
Supply and demand can be described in different terms. Almost universally, economists use value, because it circumvents difficult unit calculations. However, for cannabis, it must be described by both – value and weight. Ideally, a common unit for weight – flower equivalent units – will allow for calculations across product types.

Total supply is computed using harvest data from the inventory tracking system, then traced through the supply chain until it is ultimately sold to the customer or held as inventory. Total marijuana demand is calculated from actual sales to consumers and reported in the inventory tracking system.

Demand Calculation

Based on 2017 inventory tracking data, sales were 186.5 metric tons of flower, 19.7 metric tons of trim, 4.5 million units of packaged concentrates, 15 metric tons of concentrate material, 11.1 million infused edible units, and 1.1 million units of infused non-edible products. Together, 16.7 million units were sold of different non-flower marijuana products. Using flower equivalent measures specific to each product category, the study team converts the varying units to estimate total demand at 301.7 metric tons of marijuana flower equivalent in 2017. Figure 1 shows how each product contributes to the total sum.

Figure 1. Colorado Marijuana Demand, 2017 Actual Sales, MT of Flower Equivalent



Source: Study team calculations and methods, using state sales data.

According to the 2017 inventory tracking data, about one-third of demand by weight is for concentrates (82.4 MT), edibles (14.8 MT) and other infused products (0.9 MT). The remaining two-thirds of demand (203.6 MT) is for flower, and shake and trim sold directly to the consumer usually in the form of pre-rolled joints.

New Supply Paradigm

Starting in October 2014, new adult use business entrants were allowed into the market who were not part of a pre-existing, vertically integrated dispensary. This invited a wave of new investment and construction for cultivators and infused product manufacturing facilities (not subject to vertical integration). As these new operations came online, the subsequent supply of marijuana has grown, and production management continues to be a focal-point for regulators.

Statewide Product Flows

In order to reconcile total supply with demand, the study team traced production from the point of harvest, through the transfer and repacking system to manufacturing facilities, and finally to adult use stores and medical centers.

Figure 2 below depicts key inflection points of supply and demand throughout the inventory tracking system. For calendar year 2017, licensees reported 340.7 metric tons of marijuana flower equivalent were harvested and packaged – or actual marijuana supply. These totals represent the dried weight that was packaged for transfer as reported in the state’s inventory tracking system.

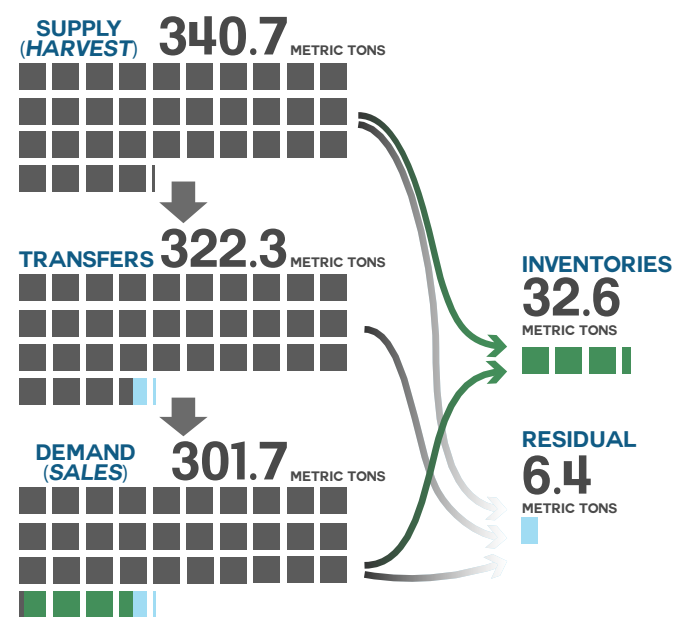
The study team used detailed transfer reports to calculate a 2017 end-of-year net inventory of 32.6 metric tons of flower equivalent for licensed businesses. Cultivation facilities accounted for 9.6 metric tons of on hand flower equivalent net inventory, while store and processing facility inventories accounted for the remaining 23.0 metric tons of flower equivalent. As shown above, total demand is 301.7 metric tons of flower equivalent. When inventories of 32.6 tons are added to this, a total of 334.3 metric tons of flower equivalent marijuana were either sold to consumers in 2017 or remained in inventory at the end of the year. The 6.4 metric tons of flower equivalent identified as residual in the inventory tracking system at the end of 2017 is discussed below.

Additional Factors in Product Flow

There is a residual between total reported supply or harvest and total reported demand (sales) plus inventories, equal to 6.4 metric tons or 1.8 percent of total supply, based on study team calculations. The residual amount occurring at the retail level is 2 metric tons, with the remaining residual amount of 4 metric tons traced to cultivation and manufacturing operations. The retail residual total in Colorado in 2017 was approximately 0.6 percent of the total retail sales, while the cultivation and manufacturing residual in 2017 was about 1.2 percent of the total harvest amount.

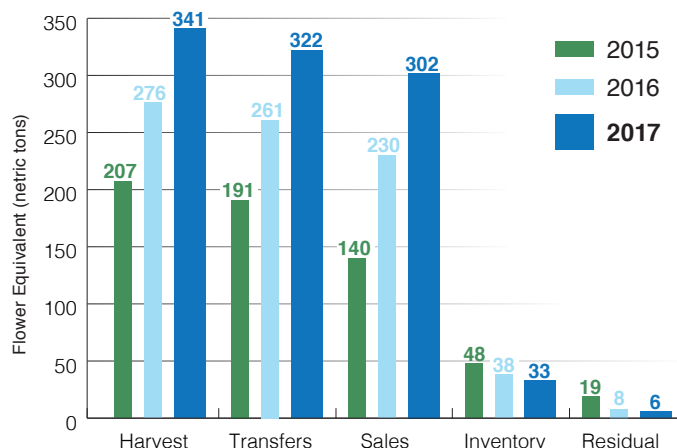
The trend over the last three years shows a decreasing residual as a percent of total production volume over time, 9.2 percent to 2.9 percent, and down to 1.8 percent in 2017, which indicates broad improvement in compliance, more accurate reporting, better internal controls, and other factors maintaining the tracking within the system from harvest to final sale. For context, general retail shrink rates in the United States range from 0.28 percent to 2.25 percent.⁷

Figure 2. Statewide Product Flows, 2017



Source: MPG, LLC, State of Colorado.

Figure 3: Product Flow Comparison, 2015 - 2017



Source: Study team calculations using state harvest, transfer, and sales data.

⁷ According to the Global Retail Theft Barometer, general U.S. retail shrink rates are 1.27 percent. Shrink rates range from 0.28 percent (big box) to 2.25 percent (pharmacies) of sales.

Figure 3 shows the product flow totals and resulting residual totals for 2015 through 2017. Colorado regulators should compare the residual figure year over year going forward to establish standards for tracking residuals.

A number of potential factors contribute to the residual figure.⁸ A key factor is the seizure of marijuana and marijuana products by law enforcement when licensees are found to be in violation of state and/or local regulations. Licensees are required to destroy non-compliant product. Another factor is the drying process as there is no standardized time in regulation to weigh the cultivated products, and the weight changes over time as the water continues to evaporate from the flower.⁹

Additional factors include failure to meet quality assurance standards, losses during the harvest and trimming process, inefficient extraction processes, inaccurate scales at harvest or sale, sales entry errors and withdrawal from packages (e.g., package adjustments without a corresponding sale), retail inventory shrinkage from employee theft or shoplifting, and potential diversion of product outside regulated channels.

The state's inventory tracking system, combined with a risk-based approach to field investigation and enforcement, allows regulators and the law enforcement community to effectively partition different components of the statewide product flows into compliant and non-compliant categories. Regulators continuously monitor product flows and take regulatory or criminal enforcement actions where necessary.

2.3 COLORADO RESIDENT & VISITOR CONSUMPTION ESTIMATION

Best practice resident consumption estimates combine the prevalence, frequency, and average quantity consumed by different consumer types together with population data. Surveys on marijuana consumption quantity are typically described using flower weight, such as “grams per day” of marijuana flower.

The study team compares actual supply and demand figures from the inventory tracking data with updated resident and tourist consumption estimates to better understand the components of demand and to estimate how much of the existing illicit market is now captured by the regulated market.

The analysis builds off the estimation methodology used in the 2014 Market Size and Demand Study—incorporating new marijuana prevalence survey data and updated visitor consumption estimates. Colorado resident consumption, which was referred to as “demand” in the 2014 study, is updated using new data from the Substance Abuse and Mental Health Services Administration (SAMHSA) National Survey on Drug Use and Health (NSDUH) and the Colorado Behavioral Risk Factor Surveillance System (BRFSS).

Potential Factors in Residual Amount

- Seizure or destruction of product by law enforcement due to regulatory infringement
 - Wet versus dry weight entries — post-harvest curing and drying (typically 2 - 4 weeks) can lead to sizeable weight differences.
 - Underreporting entry errors in the inventory tracking system database
 - Extraction yield inefficiencies
 - Removal of product for quality assurance purposes
 - Supply chain product loss
 - Retail inventory shrinkage
 - Potential diversion of product outside regulated market
-

Use Amounts per Day

Heavy marijuana consumers have been found to consume approximately 1.6 grams of flower per day. This corresponds to inhaling roughly 314 milligrams of THC per day based on 2017 average potency in Colorado of 19.6% THC content for flower.

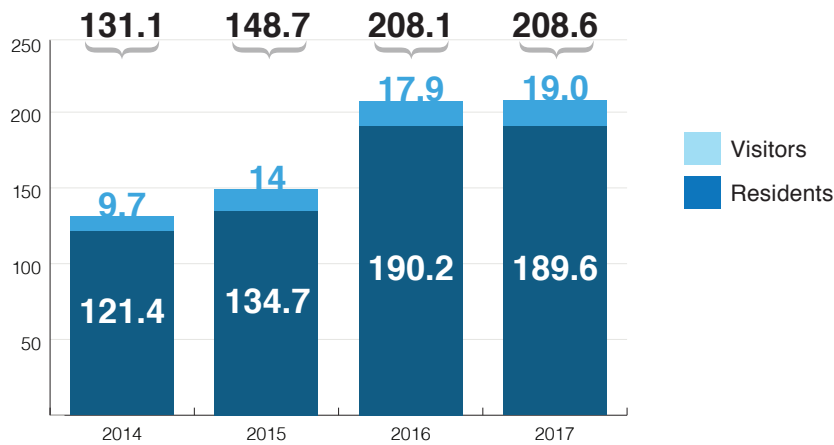
The amount of plant material necessary to produce 314 milligrams of THC will be different if the consumption method is flower, concentrates or infused products.

⁸ The inventory tracking data reveals a total residual amount but the breakdown of residual amount by factor could not be quantified.

⁹ A survey of relevant literature indicates typical drying periods range from 2 to 4 weeks and weight loss throughout the drying process averages between 15 percent and 70 percent, largely dependent upon individual strains and local climate.

Combining these data sources, we estimate total annual resident consumption to be 189.6 metric tons of flower and another 19.0 metric tons for state visitors for a total consumption of 208.6 metric tons. Figure 4 provides a summary of Colorado resident and visitor marijuana consumption estimates over the last four

Figure 4. Colorado Resident and Visitor Marijuana Consumption Estimates, 2014-2017 (Metric Tons)



Source: SAMHSA NSDUH 2014-2016; 2014-2016 Colorado BRFSS. Study team calculations.

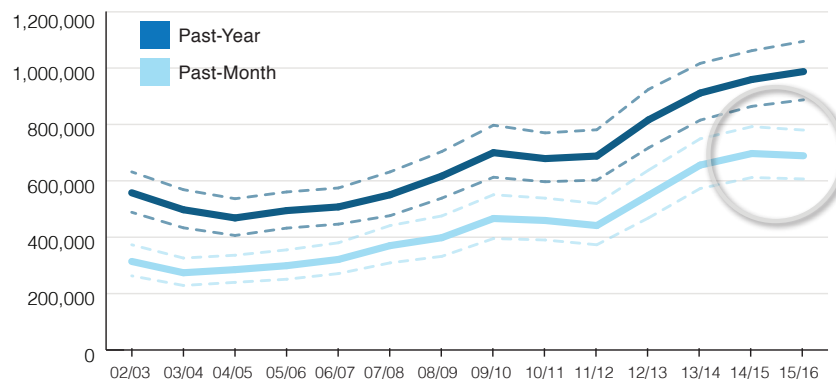
years. Growth trends are described in detail in the subsequent discussion and in Appendix A.

Marijuana consumption estimates increased steadily between 2014 and 2016 and plateaued between 2016 and 2017. The increase in estimated consumption between 2014 and 2016 can be linked to different factors, including higher consumer prevalence, higher frequency of use, and an increase in tourist visits and the state population. The decline in estimated resident consumption in 2017 can be traced to the number of reported past-month marijuana consumers. Rather than continue to increase as it has between 2014 and 2016, the number of past-month consumers decreased from 17.1 percent to 16.6 percent.

Resident Consumption Estimates

According to the NSDUH survey, the number of past-month consumers in Colorado increased by about 56 percent between the 2011/2012 survey (captured during the last year before legalization) and the most recent 2015/2016 survey (highlighted below). “Past year” consumers – who did not consume in the past month, increased by about 44 percent. Figure 5 shows the number of adult residents who reported using marijuana products within the past year and the past month, respectively. The solid line shows the point estimate and dotted lines show upper and lower bound estimates.

Figure 5: Colorado Past-Year and Past-Month Adult Marijuana Consumers



Source: SAMHSA NSDUH. 2002/03-2015/16 Population Estimates.

Total resident demand is calculated by combining estimates of adult population, marijuana use prevalence, frequency of use, and typical daily use quantities. Table 1 presents 2017 consumption estimates for Colorado residents, showing a point estimate of 189.6 metric tons. Appendix A provides a detailed discussion of the methodology.

Table 1: 2017 Consumption by Colorado Residents Age 21+ (in Metric Tons)

Frequency of Group Use (days per month)	“Group Population”	“Annual Usage Quantity (Metric Tons)”			Share of..	
		Lower Bound	Mean Estimate	Upper Bound	Users	Demand
Less than once	297,592	0.4	0.7	1.3	30.2%	0.3%
1-5	216,387	4.1	6.4	9.0	22.0%	3.4%
6-10	68,694	3.5	5.4	7.7	7.0%	2.8%
11-15	58,390	4.8	7.5	10.6	5.9%	3.9%
16-20	78,998	9.0	14.0	19.8	8.0%	7.4%
21-25	42,590	17.0	20.9	24.8	4.3%	11.0%
26-31	221,882	109.6	134.9	160.2	22.5%	71.1%
Total	984,534	148.3	189.6	233.4	100.0%	100.0%

Source: Study team calculations.

Visitor Consumption Estimate

To calculate visitor demand, the study team uses official 2016 state tourism data¹⁰ and national marijuana use survey data to project marijuana consumption patterns for visitors from different regions. In 2016, Colorado welcomed approximately 17 million out-of-state day visitors and 26.7 million out-of-state business and leisure overnight visitors, with an average length of stay of 3.6 days. The state tourism report provides the state of origin and age profile for each type of visitor. Combining these data with NSDUH survey data on adult use prevalence in each state, the study team estimates the number of annual marijuana use days by overnight and day visitors from each state, shown in Table 2 below.

Table 2: 2016 Out-of-State Visitor Marijuana Use Days, by Origin

State of Origin	% of Visitor Use Days	Visitor Use Days
CA	19.4%	3,477,792
NY	8.7%	1,068,146
FL	7.6%	923,487
TX	6.0%	1,369,107
IL	5.2%	1,555,775
KS	3.6%	516,158
NM	3.4%	31,215
AZ	2.9%	61,379
VA	2.1%	604,685
WY	0.3%	645,481
NE	0.2%	376,394
Remainder	40.7%	7,301,562
TOTAL	100.0%	17,931,182

Source: Longwoods International. Colorado Travel Year 2016. June 2017. Study team calculations.

¹⁰ 2017 tourism data were not available at report publishing time.

Based on the data, approximately 6.5 million out-of-state visitors had 17.9 million marijuana use days in 2016. Tourist data for 2017 was not yet available, so the study team assumes 2017 tourism grew six percent¹¹, bringing marijuana use days to 19.0 million. Based on national survey data, visitors consume one gram of marijuana flower per use day while visiting Colorado. These figures combine for a total visitor demand of 19.0 metric tons of marijuana flower in 2017. Estimates for visitor demand reflect increased tourist visitation, higher state and national prevalence rates, and a wider acceptance nationwide for marijuana use over previous years.¹²

Total resident and visitor consumption figures are presented in Table 3.

Table 3: 2017 Resident and Visitor Marijuana Use Days and Consumption Quantity

	Residents	Visitors	Total
Adult Marijuana Users	984,534	6,467,952	7,452,486
Annual Marijuana Use Days	139,107,010	19,007,053	158,114,064
Annual Demand (Metric Tons)	189.6	19.0	208.6
Annual Demand (Range)	(148.3 - 233.4)	(14.3 - 23.8)	(162.6 - 257.2)

Source: Study team calculations.

The study team estimates total 2017 resident and visitor consumption estimates for Colorado marijuana to be 208.6 metric tons, with residents' consumption at 189.6 metric tons and visitors at 19.0 metric tons.

2.4 Comparing Supply, Demand and Consumption

Using official data from Colorado's inventory tracking system, the study team can evaluate how resident and visitor consumption estimates compare to actual marijuana demand from official state data.

Bringing together actual demand (301.7 metric tons flower equivalent) and estimated consumption (208.6 metric tons flower), a noticeable difference is observed across these two values. As presented in Table 4, actual demand for Colorado marijuana exceeds the theoretical resident and visitor consumption point estimate by 93.1 metric tons of flower equivalent. A full discussion of results follows.

Table 4: 2017 Supply-Demand Balance Overview

Category	Value (Metric Tons)
Marijuana Demand - 2017 (Flower Equivalent)	301.7
Estimated Colorado Resident and Tourist Consumption	208.6
Potential Excess Demand	93
Range	44.5 – 139.1

Source: METRC; Study team calculations.

The difference between actual demand and estimated demand could vary between 40-140 metric tons based upon the range of estimated consumption (see appendix A).

¹¹ Colorado Business Review. https://www.colorado.edu/business/sites/default/files/attached-files/cbr_2017_issue_2.pdf

¹² The study team applies the same underreporting adjustments to tourist demand as it did to resident demand.

Discussion

The comparison in this study provides a better understanding of overlapping marijuana supply and demand – in legal and illicit markets. In 2014, the study team estimated that about 65 percent of resident and visitor consumption would be supplied through legal channels. The 2014 result suggests the presence of a lingering illicit marijuana market for Colorado residents and tourists to purchase marijuana outside of the regulated market.

In 2017, the results suggest that the state’s pre-existing illicit market for residents and visitors has been fully absorbed into the regulated market, which was a key goal of the voter-approved ballot measure in 2012 and subsequent state implementation efforts.¹³ These results also suggest there is additional demand for Colorado marijuana that is not quantified in standard resident and tourist consumption estimation techniques.

It should be noted that the supply and demand estimates include only the MED-regulated market. The figures do not include legal home grown and medical marijuana caregiver supplies, which are not considered part of the regulated market. Including these relatively small and hard-to-quantify supplies would increase the marijuana supply figures presented in this report. The study also does not consider the segment of the illicit market that grows and supplies marijuana outside of the regulated market in Colorado, often in unpermitted home grows, with the specific intention of selling outside of the state. The study only considers consumption of marijuana by Colorado residents and tourists, which can now be fully supplied by the regulated market.

Supply, demand and estimated consumption have changed in this study, because unlike previous studies, this assessment uses official sales data and converts these sales into flower equivalent, something that has not been done before. A combination of the following factors can influence the estimate of supply, demand and estimated consumption:

- **At home inventory.** The Colorado resident and tourist consumption estimate is a measure of how much marijuana is consumed by residents and tourists and says nothing about actual consumer purchases. Conversely, the official sales data that are converted into flower equivalent says nothing about how much is being consumed. As with other consumer products, it is highly likely that some marijuana consumers will purchase a product that is kept for a long time or never completely consumed, creating a statewide home inventory of marijuana products that are captured in the demand figure but not the consumption estimate.
- **Non-flower products.** The federal NSDUH prevalence survey and existing consumption surveys do not account very well for the presence of non-flower products. Non-flower products are relatively new and federal surveys have not been fully adjusted to account for their use. While the study team converts non-flower sales into marijuana flower equivalent, consumers may be effectively purchasing more non-flower products on a flower equivalent basis than if they purchased flower itself—the novice or average consumer may find it difficult to conceptualize 100 mg of edible products or 0.5 g of concentrate product. If this is the case, as non-flower product market share increases, this discrepancy will become more pronounced. This also demonstrates the need to better understand frequency of use and usage patterns associated with non-flower products.
- **Visitor quantification.** The study team’s methodology for calculating visitor marijuana demand relies on visitors’ state of origin and applying the corresponding federal NSDUH survey data. State tourism accounting likely does not accurately capture the number of “sole-purpose” visitors—those visitors choosing Colorado exclusively for its legalized marijuana market, and the existing consumption surveys do not account for the likely higher than the average consumption from those visitors.
- **Excluded age cohorts.** The consumption estimate only includes individuals age 21 and over, the legal age to purchase regulated marijuana in Colorado. However, the NSDUH survey data show that there are individuals under the age of 21 who

¹³ Colorado Constitution, Article XVIII, Section 16, Subsection (1)(b)(iv)

consume marijuana, and it seems reasonable that the source for some portion of the marijuana consumed is from the regulated market (initial purchaser of marijuana could be of legal age).

- **External demand.** None of Colorado's bordering states have adult use marijuana markets; in fact, Colorado is the closest regulated adult use market to the major population centers in the Midwest and East Coast (as of December 2017). Marijuana products are significantly more valuable in states with prohibitive marijuana policies. There is a strong profit incentive to buy marijuana in Colorado for transport to other states, where it is more legally risky and difficult to obtain. Observed regional sales data (presented in Section 3.5.2) indicate high per capita sales in several border regions, which further supports the existence of sales in these areas to non-residents who drive to Colorado to purchase marijuana legally and then return to their origin. This illegal activity is expected to decrease as other states adopt less-prohibitive policies towards marijuana.

The study signals the need to monitor and establish standard values for key regulatory performance metrics (i.e., demand, inventories, residual values, consumption) over time, and in comparison to other states with regulated markets. The flower-equivalent measures employed in this analysis could prove to facilitate more meaningful analysis of non-flower product relation to flower and trim inputs and inventory trends.

Stakeholders should also work to improve demand-side data collection, which will allow for improved accuracy of resident and visitor consumption estimates. The analysis identifies the need to improve upon current survey efforts, which target many forms of substance use and mental health issues, by focusing more closely on marijuana consumption in its varying forms. Currently, the surveys only include questions on marijuana flower consumption.

When taken together, however, the results of the study indicate that the illicit market for resident and visitor marijuana has been largely, if not entirely, absorbed into the legal market, where it is regulated and taxed for the protection of public health and safety.

3 REGULATED MARKET TRENDS

This section provides an in-depth analysis of regulated market trends in Colorado, which is the longest operating and, arguably, most sophisticated legal market in the nation at the present time. The regulated market trends are particularly interesting in the context of Colorado's legalization approach versus different approaches taken in other states and countries. These trends may assist policymakers to see how markets might evolve in their own state or country. Of course, where other jurisdictions choose different rules from the Colorado model, one can expect different outcomes.

Key Findings

This section contains detailed time series and geographical depictions of trends and patterns in both the medical and adult use marijuana markets. All data in this section are sourced from the state inventory tracking system. Over time, the regulated market has evolved in prices and potency, while the characteristics of local marijuana markets within Colorado vary greatly. These trends and patterns are likely influenced by several factors. Several key findings emerge from these analyses and are summarized below.

Regulated Marijuana Market Product Pre-tax Price Trends

- Adult use prices are declining in general. From 2014 through 2017, average annual adult use flower prices fell 62.0 percent, from \$14.05 to \$5.34 per gram weighted average. Over the same period, adult use concentrate prices fell 47.9 percent, from \$41.43 to \$21.57 per gram. Adult use infused edible prices hovered around \$18.00 per 100mg package but have not exhibited a consistent trend over time.
- Prices for medical marijuana products have declined over the past four years at a pace similar to the adult use market (in terms of percentage decline). Average medical flower prices fell 40.9 percent, from \$5.55 per gram in 2014 to \$3.28 at the end of 2017. Medical concentrate prices declined 34.6 percent, from \$25.83 per gram to \$16.89, over the same period, and the average price for a 100 mg medical infused edible hovered around \$9.00.
- Falling prices in both markets have several implications for consumers, producers, and governments. For consumers, lower prices mean more affordable marijuana, which will likely increase overall demand and total sales, but may also increase addiction and dependency rates.¹⁴ In most cases, producers and retailers operate with narrowing profit margins as prices fall, putting pressure on the less-efficient and often smaller businesses. Since sales tax revenues are based on retail prices, per unit tax revenues will fall as prices fall. However, public revenues will likely continue to rise if sales volumes are increasing overall. As market growth slows and prices fall, tax revenues will eventually plateau.

Marijuana Product Potency Trends

- According to state testing data, average marijuana flower potency has increased slightly since 2014. While the data contains some flower samples with up to 30-35 percent THC, the average THC content of all tested flower in 2017 was 19.6 percent statewide compared to 17.4 percent in 2016, 16.6 percent in 2015, and 16.4 percent in 2014. This trend indicates a slow but steady increase in flower potency.
- The average potency of concentrated extract products increased steadily from

¹⁴ American Society of Addiction Medicine. https://www.asam.org/docs/default-source/public-policy-statements/state-level-proposals-to-legalize-marijuana-final2773DD668C2D.pdf?sfvrsn=e6c7ad4_2

56.6 percent THC content by weight in 2014 to 68.6 percent at the end of 2017. While there are concentrate products with potency at 90 percent or above, such products are outliers, and when considering all forms of concentrates (wax, shatter, oil, vape pens, etc.), the true average is much lower.

- The increase in average potency, combined with falling prices, result in falling prices per “serving” of THC for most products on the market. This trend means that consumers can achieve the same psychoactive and therapeutic effects at lower prices as the market continues to mature.

Geographical Trends

- Edibles account for 13 percent of the overall adult use market, but account for nearly 25 percent of the market in tourist areas.¹⁵ For individuals traveling to tourist destinations, edibles provide a smokeless form of consumption that may appeal to inexperienced marijuana consumers, non-smokers or tourists with limited spaces for consumption.¹⁶
- Higher marijuana prices are more common in areas with fewer dispensaries compared to tourist areas. This pattern suggests that competition is a more important factor for regional pricing and margins than tourist demand.
- Per capita sales are high in regions with large numbers of annual visitors, including border regions, which indicates that visitors account for a sizable portion of sales.
- The medical marijuana market still accounts for a major component of the overall marijuana market in the Front Range and Denver Metro area. Colorado lawmakers, regulators, and researchers did not necessarily expect a medical market of this size to endure since there would be no barrier to accessing the adult use market beyond proof of age, whereas medical patients must qualify and apply for a medical card.¹⁷ The lower pricing and abundance of medical marijuana centers are attractive to the patient population that is more likely to live near or travel to the more developed Front Range medical infrastructure.

3.1 PRICE TRENDS BY UNIT AND WEIGHT

The study team computed the weighted-average pre-tax price of marijuana products for each regulated market based on state inventory tracking sales data.

In general, average prices for adult use marijuana products declined significantly from 2014 to 2017. The largest price declines were seen in concentrates¹⁸, which fell 47.9 percent, from \$41.43 to \$21.57 per gram. The price of one gram of adult use flower exhibited a steady downward trend, decreasing 62.0 percent, from \$14.05 to \$5.34 per gram. For the past three and a half years, packages of adult use infused edible products containing 100 mg of THC stayed relatively constant around \$18, with no clear trend over time.

From 2014 to 2017, the average price per gram for medical flower fell 40.9 percent, from \$5.55 to \$3.28 per gram. Over the same period, the price of concentrates in the medical marijuana market decreased 34.6 percent, from \$25.83 to \$16.89 per gram. Medical infused edibles sold in 100 mg THC packages have consistently cost around \$9.00, with a slight downward trend over time. Figure 6 illustrates the price trends for these marijuana products in both markets.

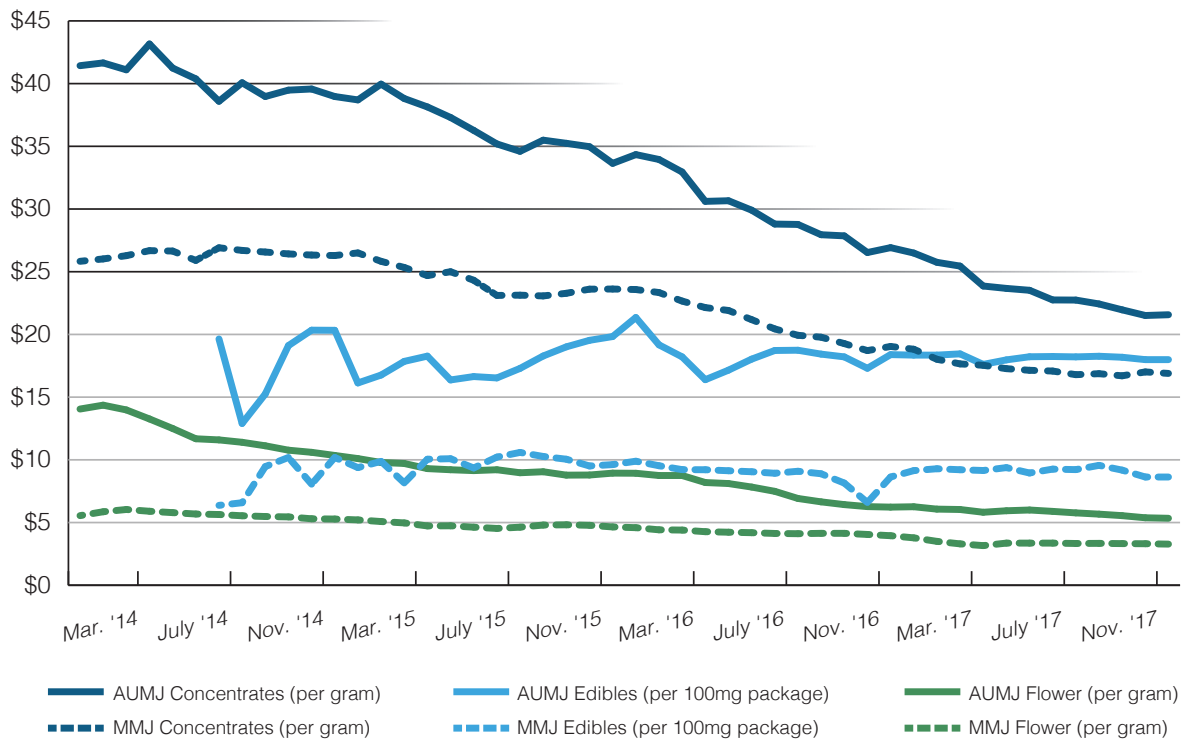
¹⁵ Tourist areas for this report are defined as Clear Creek, Eagle, Gilpin, Grand, Gunnison, Pitkin, Routt, San Miguel and Summit Counties.

¹⁶ Public consumption of marijuana products is forbidden in Colorado and most hotels do not allow smoking or vaporization indoors.

¹⁷ See Scott, Dylan. Marijuana Legalization Blurs Lines Between Medicinal and Retail Dispensaries. [Governing.com](http://www.governing.com/topics/public-justice-safety/gov-marijuana-legalization-blurs-lines.html), July 2013. <http://www.governing.com/topics/public-justice-safety/gov-marijuana-legalization-blurs-lines.html>.

¹⁸ It is important to note that there are many different types of concentrates (i.e., wax, shatter, oils, cartridges, etc.) with significantly different pricing. Businesses have the ability to individually identify each type in their unique way; because of this, it is difficult to separate each type so the prices presented here include all forms of concentrated extracts.

Figure 6: Price Trends for Marijuana Products in Colorado



Source: Study team calculations using state sales data.

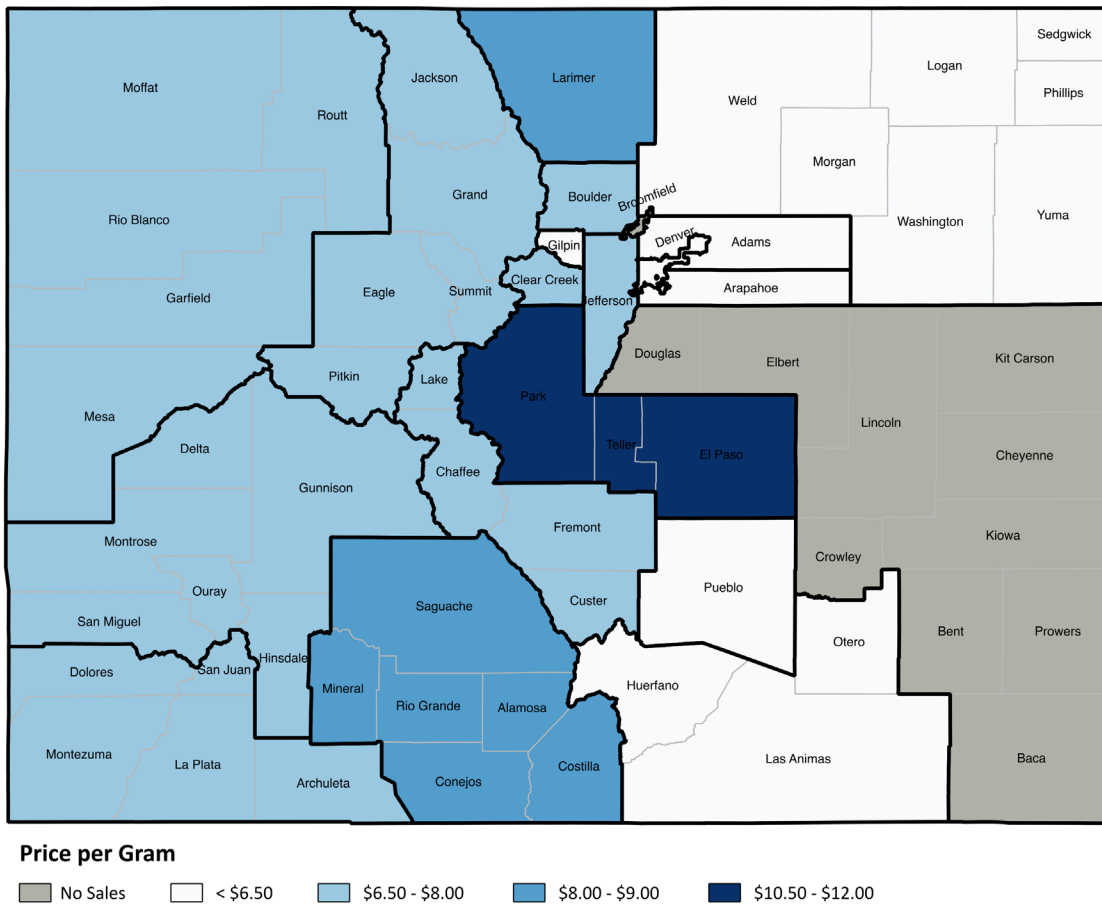
Prices exhibited substantial geographic variation within the state. In line with standard competition theory, regions with more outlets had lower average prices, and regions with few outlets had prices that were above the state average. The following figures illustrate the weighted-average regional price per gram of marijuana products in the adult use and medical marijuana markets.^{19,20,21}

¹⁹ In order to comply with state taxpayer confidentiality requirements and to provide consistency, we aggregate county-level data based on adjustments to the Colorado Planning and Management Regions as defined by the Colorado Department of Local Affairs.

²⁰ Under Colorado Revised Statutes §39-21-113(4), any data derived from taxpayer returns must be combined in order to protect the confidentiality of individual taxpayers when there are fewer than three taxpayers in a given category, or any one of them represents more than 80 percent of the total.

²¹ A map and table of the official Colorado Planning and Management Regions is included in Appendix B.

Figure 7. Adult Use Marijuana Flower – Weighted Average Price per Gram, 2017

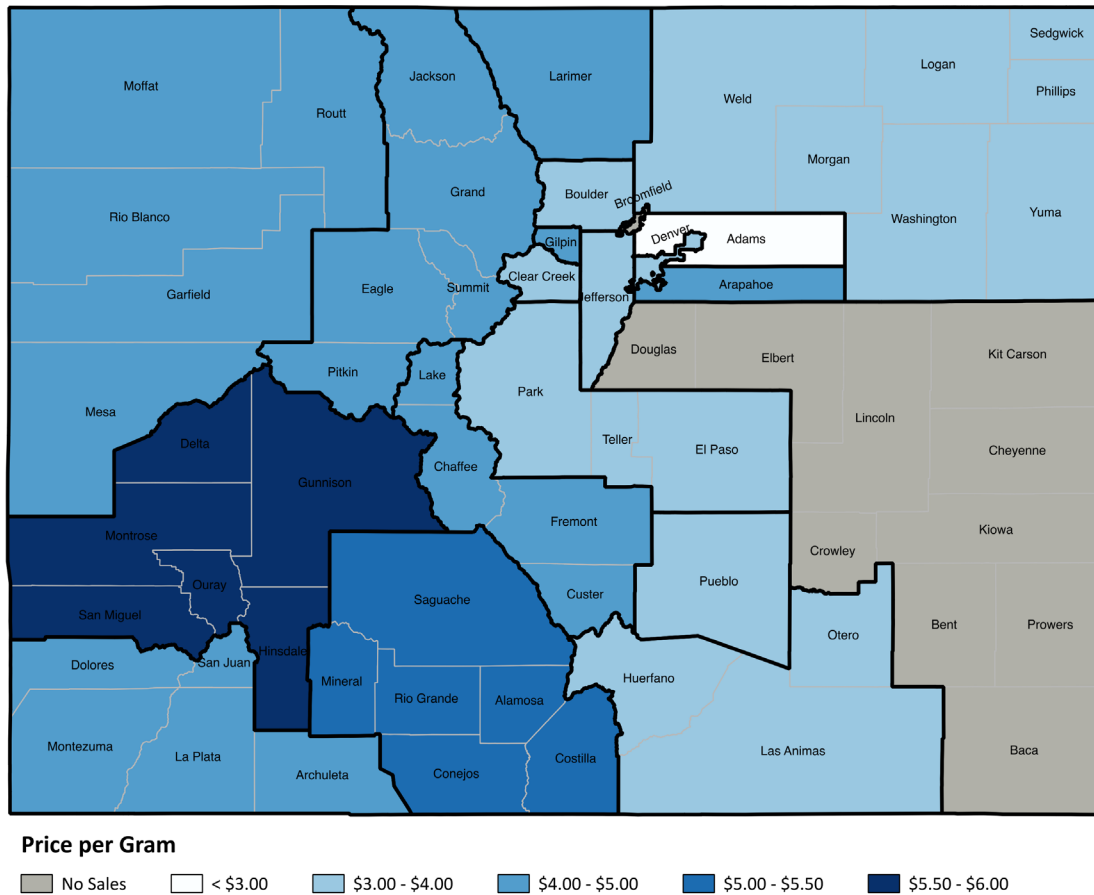


Source: Study team calculations using state sales data.

The statewide average price per gram of adult use flower in 2017 was \$5.79. The lowest prices for adult use flower were found in Denver County at \$4.57 per gram. Adult use flower is also priced lower in the more populous counties along the I-70 corridor and in the central part of the state, ranging from \$6.50 to \$9.00 per gram. The most expensive adult use flower was found in Larimer County and the region comprising Park, Teller, and El Paso counties, with weighted average per gram prices of over \$8.30 and \$11.75, respectively. In general, lower adult use flower prices tend to be found in counties with a high density of retail outlets, reflecting increased competition.

Prices in the medical market also vary across the state. Figure 8 below illustrates the geographic variation in medical marijuana flower prices.

Figure 8: Medical Marijuana Flower – Weighted Average Price per Gram, 2017



Source: Study team calculations using state sales data.

In 2017, the statewide weighted average price per gram for medical flower was \$3.36. The highest medical flower prices were observed in the counties of the Western Slope region (Delta, Gunnison, Montrose, San Miguel, Ouray, and Hinsdale), with an average price of \$5.52 per gram. As with adult use flower, lower prices are generally observed in the populous central regions and counties, with patients in Denver paying \$3.12 per gram, which is second only to Adams County at \$2.99 per gram.

Table 6 provides 2017 prices for four counties. Denver and Boulder counties represent typical metropolitan areas. Eagle and Summit counties characterize mountain resort areas where visitors engage in activities such as skiing, camping, and hiking. Summit County has the highest prices in three out the four product categories (adult use flower, medical flower, and adult use concentrate), while Boulder County has the highest price for medical concentrate. Denver has the lowest prices across all product categories.

Table 6: 2017 Pricing for Marijuana Products in Colorado

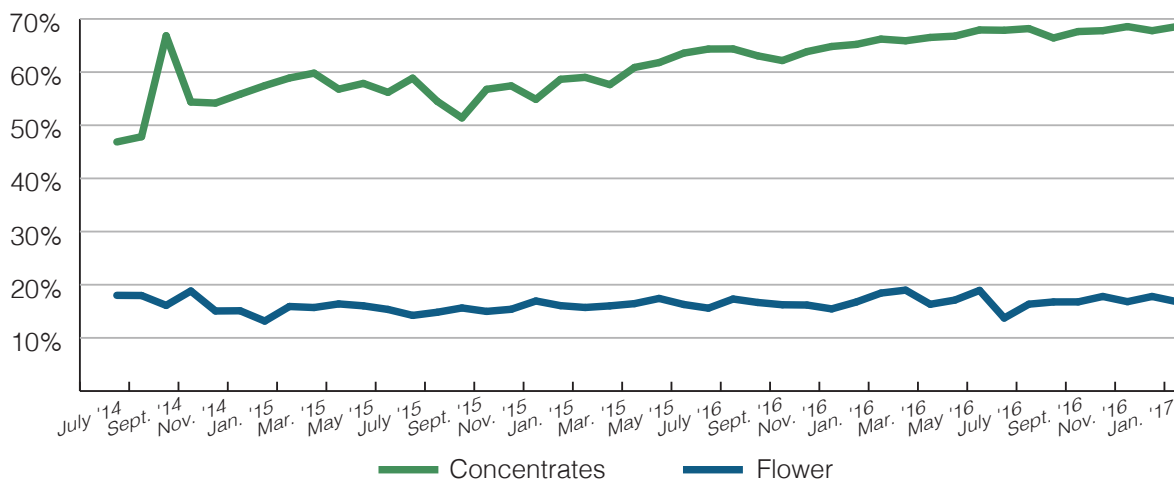
Market	Colorado	Denver County	Boulder County	Summit County	Eagle County
Price per Gram of Flower - 2017 Weighted Average					
Medical	\$3.36	\$3.12	\$3.90	\$4.37	\$4.46
Adult Use	\$5.79	\$4.82	\$7.05	\$7.17	\$7.08
Price per Gram of Concentrate - 2017 Weighted Average					
Medical	\$17.25	\$15.89	\$20.44	\$19.15	\$17.53
Adult Use	\$23.23	\$20.38	\$24.18	\$27.02	\$24.63

Source: Study team calculations using state inventory tracking data.

3.2 POTENCY TRENDS

In 2014, Colorado began implementing mandatory testing requirements for adult use marijuana products. Since then, potency and contaminant testing were required for adult use marijuana products, although similar regulations did not apply to medical marijuana products until November 2016. This state laboratory testing data allow the study team to examine potency trends for adult use flower and concentrates, illustrated in Figure 9 below.²²

Figure 9: Potency Trends for Marijuana Products in Colorado



Source: Study team calculations using state laboratory testing data.

The average potency of flower has remained fairly steady from 2014 through 2017, with a slight increase in trend from 16.4 percent in 2014 to 16.6 percent in 2015, 17.4 percent in 2016, and 19.6 percent in 2017.²³ In 2017, the highest flower potency consistently observed was between 20 and 25 percent.²⁴ The relatively flat trend in flower potency suggests that while a small number of skilled growers are able to achieve high THC content, the average grower is producing only a slightly more potent flower over time.

The average potency of concentrated products has increased steadily since 2014, from 56.6 percent to 68.6 percent at the end of 2017, a 21.2 percent increase. As with flower, certain concentrate batches tested significantly higher than the average potency, with several observations over 80 percent. In recent years, the proportion of higher-potency concentrates has increased significantly. In 2015, only 5 percent of the testing results for concentrates were higher than 75 percent THC content. However, in 2017 the share of concentrate test results with over 75 percent THC increased to 24.7 percent.

The market for concentrates has evolved rapidly with a wide range of products, such as wax, shatter, oil, vaporizer cartridges, etc., each with varying average levels of THC. The state laboratory testing data do not allow us to reliably distinguish between these subcategories of concentrates, and future research with improved data will provide more insights into the range of concentrates on the market and the trend toward higher-potency products.

3.3 “PRICE PER SERVING” TRENDS

The price trends discussed above use weight or unit measures to demonstrate the price. However, due to changes in potency and patterns of consumption, that simple pricing model is becoming less relevant. A new pricing model—called the “price per serving”—can reveal more directly how much consumers are paying to achieve the same psychoactive effects across different product types and whether a “high

²² Due to the prevalence of dual-licensed businesses, medical and adult use products are often cultivated and produced in an identical manner. For flower and concentrated extracts, the product mix available in both markets is very similar. The study team considers potency testing results from the adult use market to also be representative of the medical market.

²³ Lab testing data reports THCa and THC content by weight; however, total active THC content is only realized once THCa undergoes decarboxylation. Prior to this conversion, THCa has a molecular mass that is 12.3 percent more than THC. To calculate pre-decarboxylation Total Active THC from the lab results for this report, the study team uses the following calculation for flower and concentrates: Total THC = THCa * (0.877) + THC.

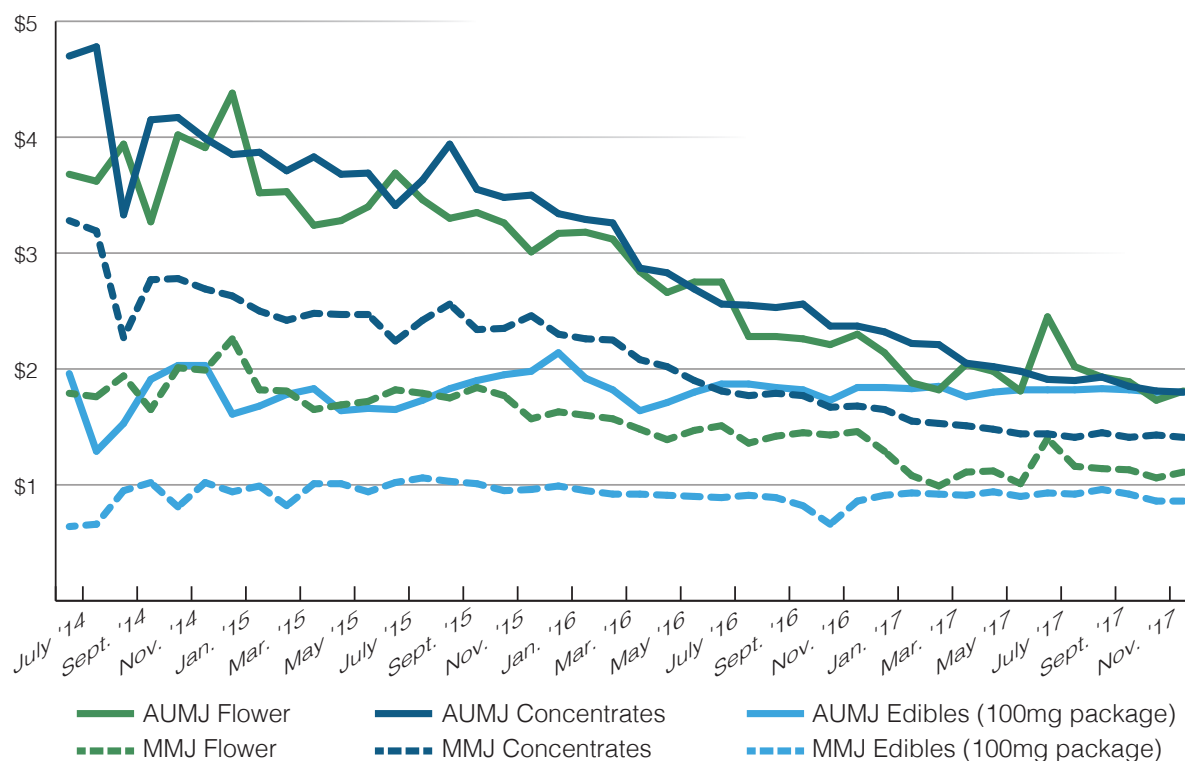
²⁴ The study team’s potency calculation yields more accurate but slightly lower potency values than the commonly reported method of simply adding THC and THCa.

THC/low price” paradigm is emerging as concentrated products become more popular and as smoking flower marijuana becomes less prevalent.

We rely upon the state regulations that define a single serving for adult use marijuana edibles to be 10 mg of THC to derive the common denominator of a “serving.”²⁵ We do not attempt to specify exactly what a standard serving size is, but rather use the state’s description of one serving of edible THC as a basis for one “serving.” It is important to note that we use the word “serving” simply to describe a quantity of THC by consumption method, not as a reference to medical value or a recommendation to consumers.

The study team combines state price and potency data with the results from its 2015 equivalency study to make these calculations.²⁶ Ingested THC has a relative effectiveness factor of 5.71 compared to inhaled THC, so an equivalent serving size of smoked marijuana products (flower and concentrates, including hash, wax, shatter, and cartridges) is 57.1 mg of THC, based on the state designation of 10 mg of edible THC as one serving size for packaging requirement purposes. Combining the monthly average potency and weighted average prices per gram of each adult use product, the average price per serving can be computed for each product type.²⁷ Figure 10 illustrates how the price per serving of THC has changed over time for marijuana products in the adult use and medical marijuana markets.

Figure 10: Price per THC Serving Trends for Marijuana Products in Colorado



Source: Study team calculations using state sales and laboratory testing data.

In 2017, edibles purchased in 100 mg packages cost an average of \$1.80 per 10 mg serving of ingested THC in the adult use market and \$0.86 in the medical market. The price trends of infused edibles in both markets remained relatively flat over the past four years, although short-term fluctuations are observed.

The average cost of a 57.1 mg serving of inhaled THC from adult use flower has decreased 50.8 percent, from \$3.68 in 2014 to \$1.81 in 2017. A serving of THC from medical flower cost an average of \$1.11 in 2017, down 40.0 percent from the 2014 average of \$1.79. In both cases, the rate of decline in price-per-serving outpaced the price-per-gram declines, due to a combination of falling flower prices and slightly increasing potency from 2014 through 2017.

²⁵ Marijuana Enforcement Division - Code of Colorado Regulations (1 CCR 212-2). R 103 – Definitions. “Standardized Serving Of Marijuana” means a standardized single serving of active THC. The size of a Standardized Serving Of Marijuana shall be no more than 10mg of active THC.”

²⁶ Marijuana Policy Group. (2015). “Marijuana Equivalency in Portion and Dosage.” https://www.colorado.gov/pacific/sites/default/files/MED%20Equivalency_Final%2008102015_1.pdf

²⁷ The study team calculates potency as the total THC content, by weight (%), using the following calculation: THCa * (0.877) + THC.

The cost of a serving of THC from concentrated extract products exhibited the largest decrease of all marijuana products in both markets. The average price of a serving of THC from adult use concentrates fell 61.7 percent, from \$4.70 in 2014 to \$1.80 in 2017, while a serving from medical concentrates fell 57.0 percent, from \$3.28 in 2014 to \$1.41 in 2017. Once again, the price per serving of concentrated THC fell significantly faster than the per gram price of concentrates due to the increase in average potency from 2014 to 2017, coupled with a steady decline in concentrate prices.

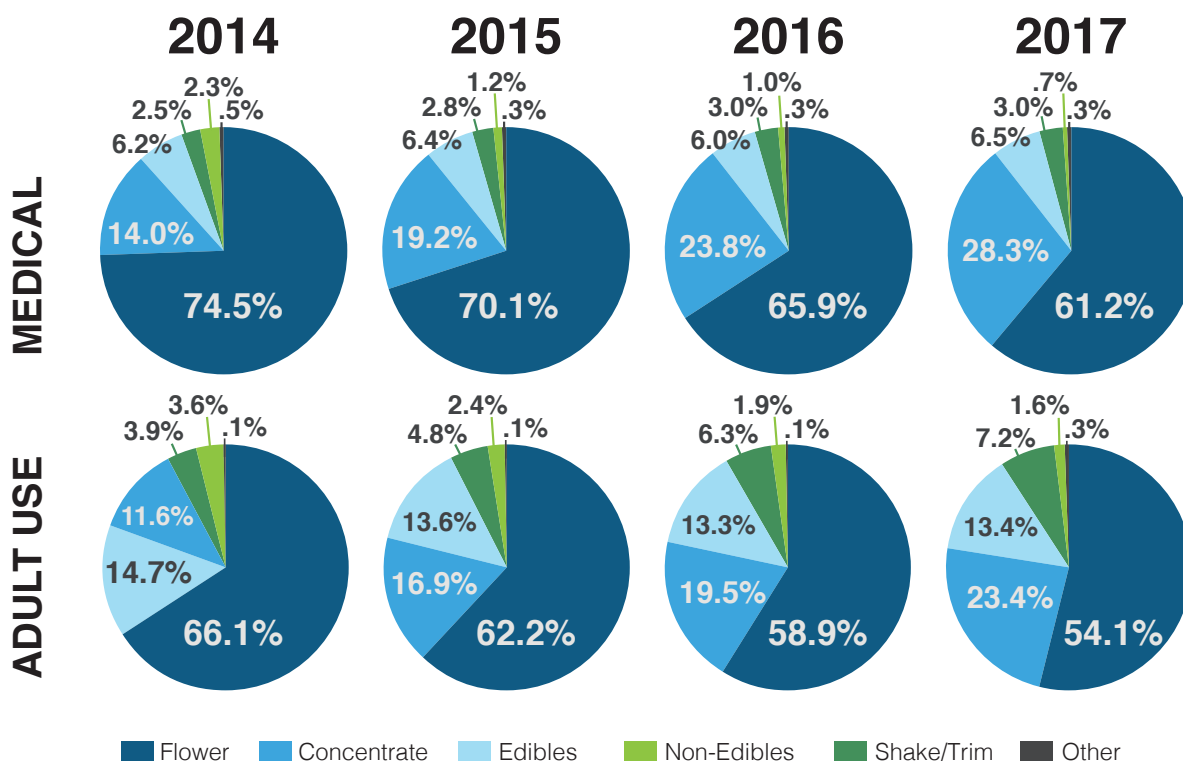
The trends presented above reflect an increasingly competitive market. As producers and retailers improve their operations and achieve economies of scale, prices have declined to account for lower production costs. At the same time, as the market matures and consumers grow accustomed to lower prices, producers and retailers are increasingly competing for business by offering lower prices.

3.4 PRODUCT SHARES

In order to understand the market shares for each marijuana product type, the study team examined inventory tracking system data on product sales by value. The study team calculated market shares for each product for the medical and adult use markets in 2014 through 2017. It is important to note that the product market shares by sales are different from the market share based on the flower equivalent quantities of each product sold (see Figure 3).

A notable shift in product mix occurred in both markets from 2014 through 2017. The proportion of flower sales decreased from 74.5 to 61.2 percent in the medical market and from 66.1 to 54.1 percent in the adult use market. At the same time, the share of concentrate sales increased steadily, from 14.0 to 28.3 percent in the medical market and 11.6 to 23.4 percent in the adult use market. This shift illustrates the continued growth in popularity of concentrates. The relatively stable market shares for other products, combined with the falling price per serving from concentrates, suggest that consumers in both markets are switching from flower to concentrates. Figure 11 illustrates the total sales and corresponding market share for each product type.

Figure 11: Product Type Market Share, by Year and Market

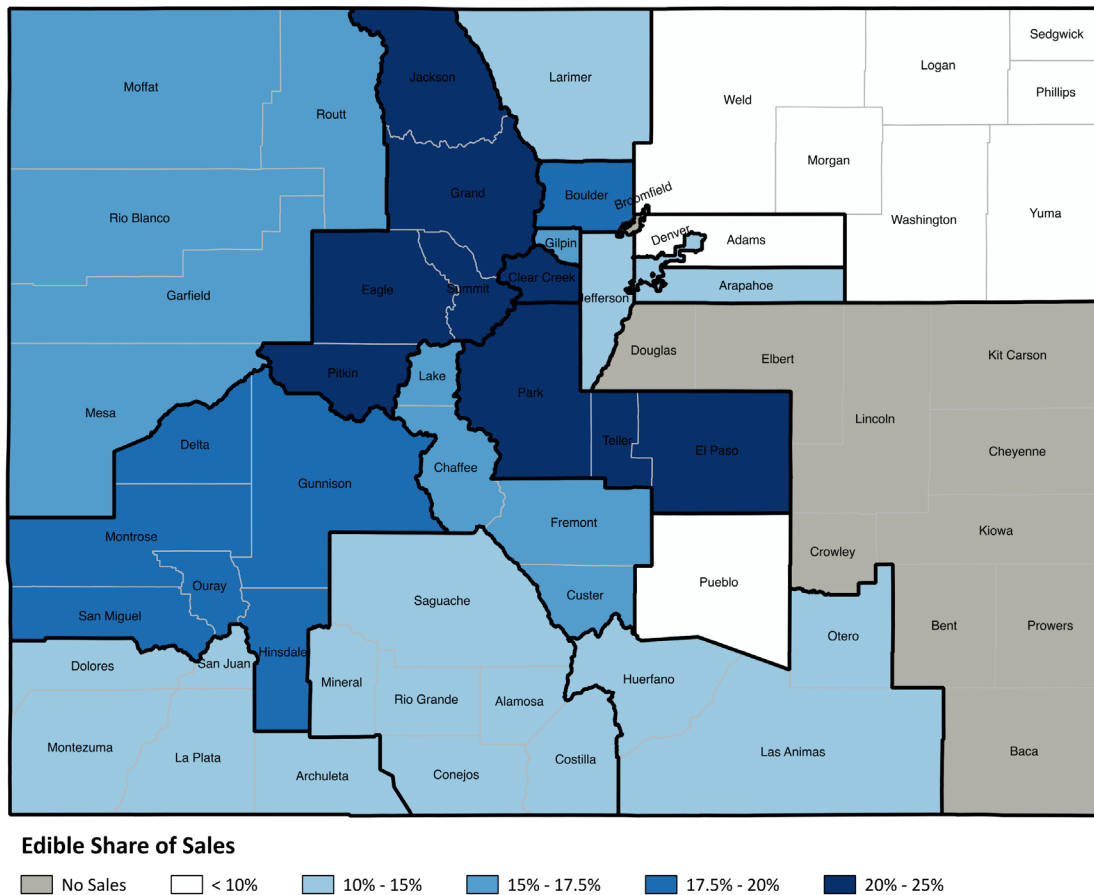


Source: Study team calculations using state sales data.
 Note: "Other" sales includes immature plants, seeds and related products.

3.5 Regional Product Shares – Adult Use Marijuana Market

There are wide geographic differences in the market shares for marijuana products. Edibles accounted for 13.4 percent of all adult use marijuana sales in 2017. Figure 12 shows that edibles account for a sizable portion of all adult use marijuana sales in many areas. In the mountain tourist region (Jackson, Grand, Summit, Eagle, and Pitkin counties), central Colorado region (Park, Teller, and El Paso counties), and Clear Creek County, marijuana-infused edibles account for almost a quarter of all adult use marijuana sales. For individuals traveling to tourist destinations, edibles provide a smokeless form of consumption that may appeal to inexperienced marijuana consumers or non-smokers. Edibles also provide an inconspicuous consumption form for tourists given the illegality of consuming marijuana and marijuana products on public lands/public spaces, as well as many tourist accommodations (hotels, private rentals, etc.) banning marijuana use on the premises.

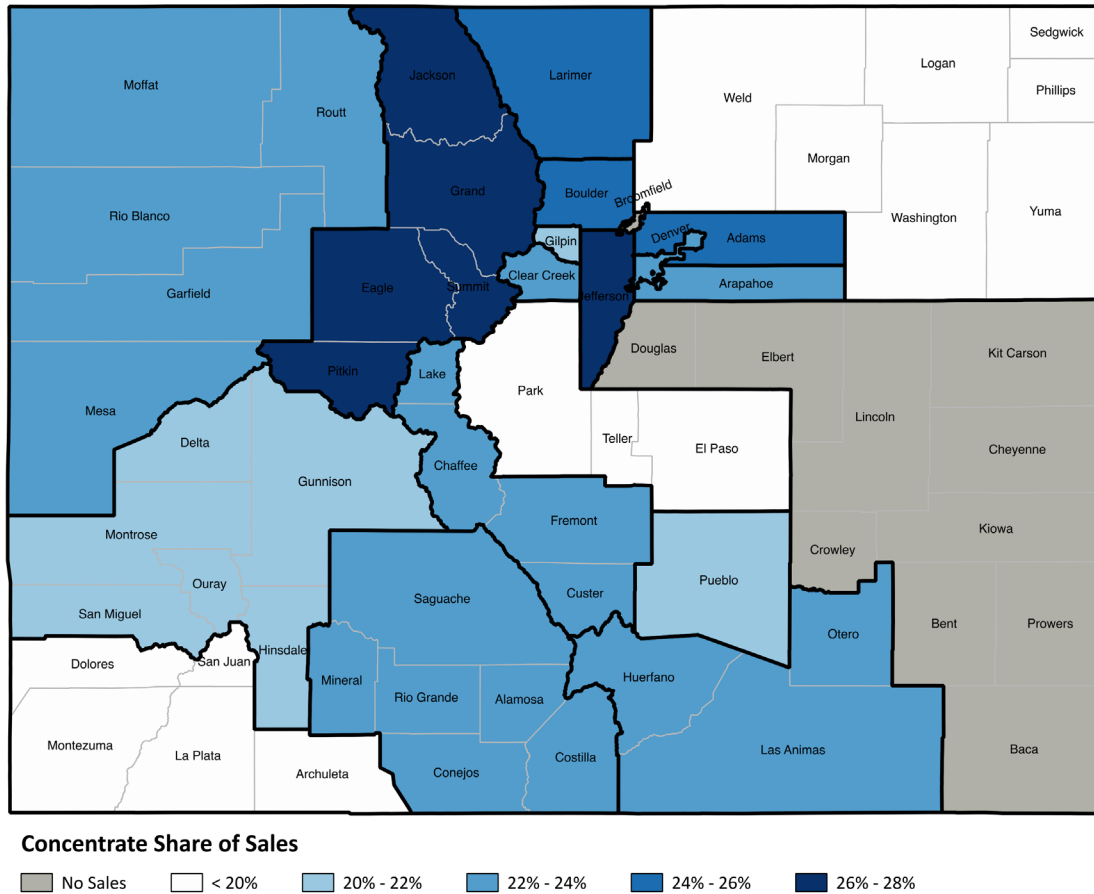
Figure 12: Infused Edible Share of Total Sales in Adult Use Market, 2017



Source: Study team calculations using state sales data.

Figure 13 illustrates the proportion of adult use marijuana sales of concentrated extract products. Statewide, concentrates made up 23.4 percent of all 2017 adult use marijuana sales. The share of adult use concentrate sales is particularly high in the mountain tourist region (Jackson, Grand, Summit, Eagle, and Pitkin counties) and Jefferson County, accounting for 27 percent and 26 percent, respectively. The northeastern region, southwestern region, and central region had the lowest concentrate share of adult use sales, all below 20 percent.

Figure 13: Concentrate Share of Total Sales in Adult Use Market, 2017

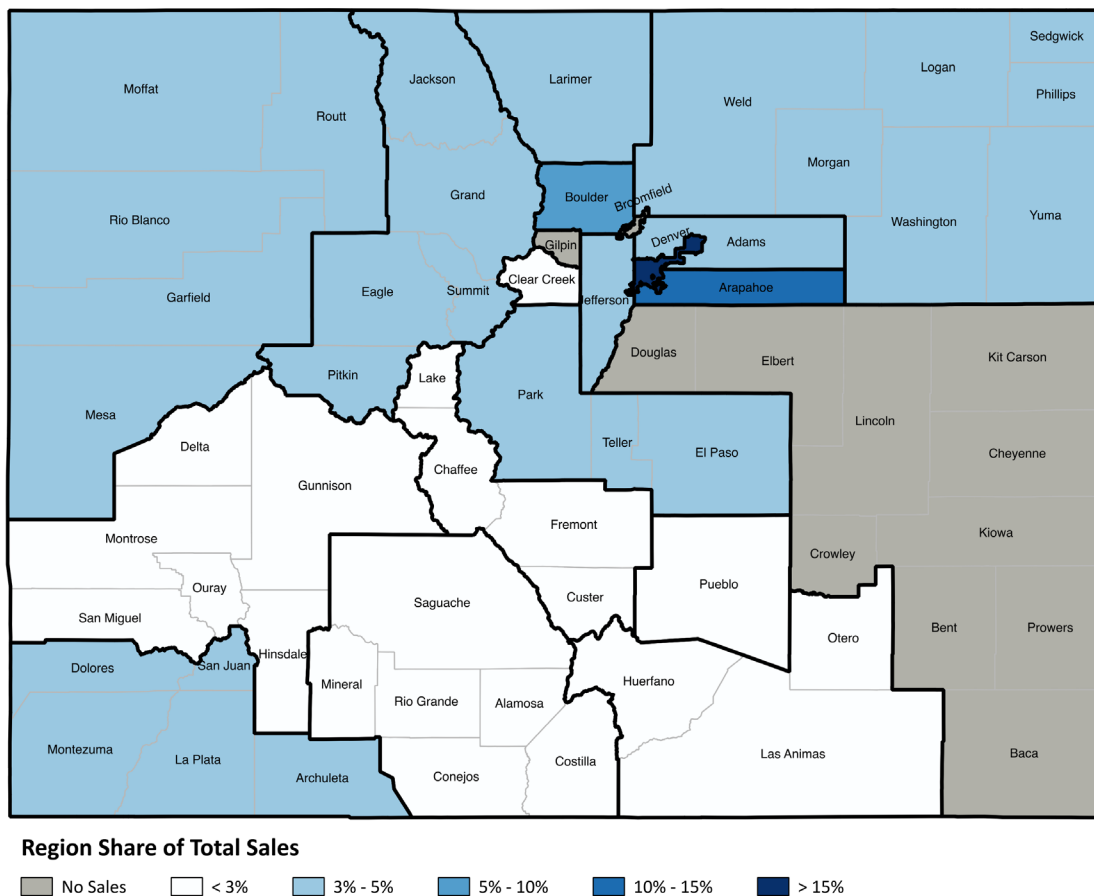


Source: Study team calculations using state sales data.

3.6 TOTAL SALES AND PER CAPITA SPENDING

Reflecting the state’s population distribution, the majority of adult use marijuana sales in Colorado in 2017 occurred in Front Range counties. Figure 14 illustrates each region’s proportion of the state’s total marijuana sales in 2017.

Figure 14: Share of Statewide Total Adult Use Sales, 2017

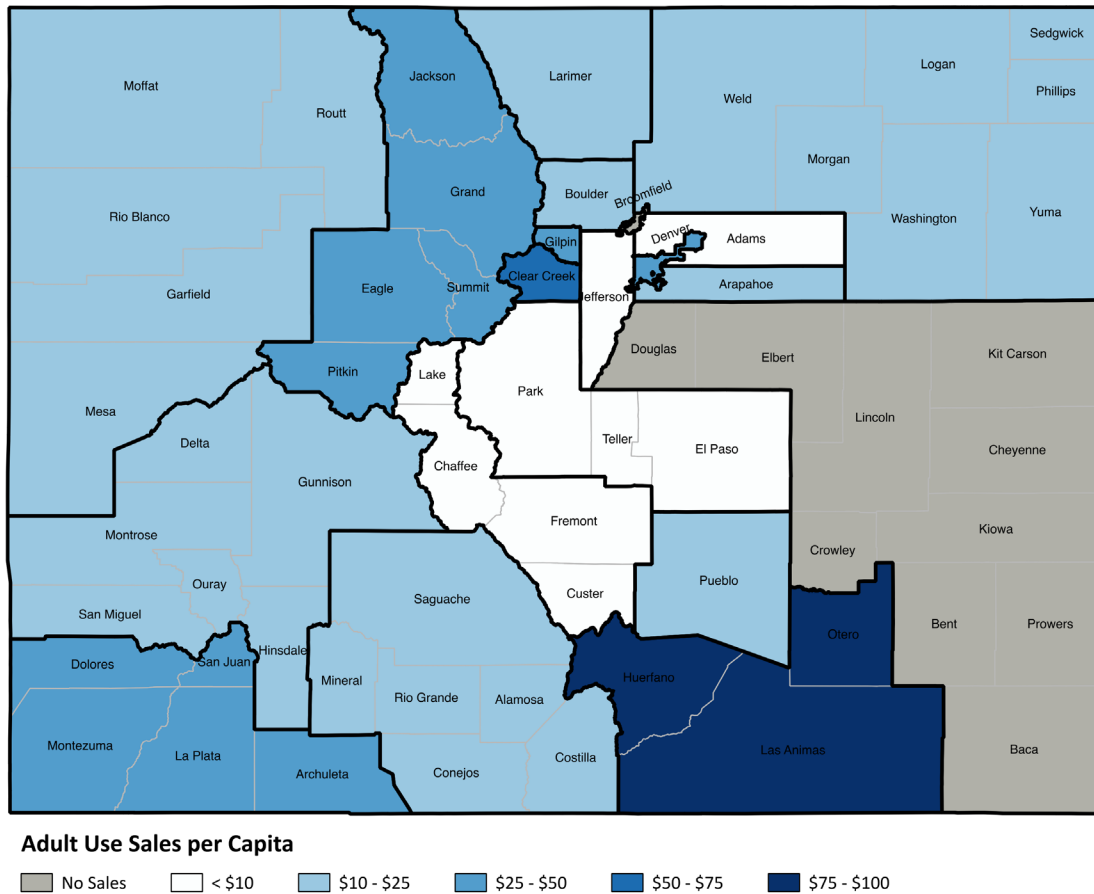


Source: Study team calculations using state sales data.

Denver County, which is home to 13 percent of the Colorado population, accounted for nearly 34 percent of all marijuana sales in 2017. The broader Denver Metro Area (Adams, Arapahoe, Broomfield, Denver, Douglas, and Jefferson counties)—51 percent of the state population) combined for 54.9 percent of the state marijuana sales, even though Broomfield and Douglas counties had no legal sales in 2017. The more populous Boulder and Larimer counties contributed 7 and 5 percent of all 2017 sales, respectively. In general, marijuana sales correlate closely with population. This pattern remains consistent across regions when distinguishing between adult use and medical marijuana sales.

Monthly per capita marijuana expenditure patterns also exhibit geographic variability across Colorado. The statewide average per capita monthly expenditures on adult use marijuana was \$16.46. Figure 15 illustrates the per capita adult use marijuana sales by region.

Figure 15: Monthly per Capita Adult Use Sales, 2017



Source: U.S. Census Bureau.
Study team calculations using state sales data.

The figure above reveals that the highest average monthly per capita sales of adult use marijuana occurred in the southern Colorado region comprising Huerfano, Las Animas, and Otero counties, with \$98 in adult use sales per month per resident. Clear Creek (\$60), Gilpin (\$50), and Denver (\$45) counties followed. The differences observed across counties is likely caused by a significant number of out-of-state visitor purchases, which inflate the per capita calculation. It is important to note that data are not available on the origin of marijuana consumers; these per capita figures therefore reflect the total sales to residents, as well as transient populations, tourists, and travelers along the main highways.

4 EMERGING TOPICS

4.1 LICENSE ALLOCATION

In Colorado, there are parallel licensing systems for medical and adult use production and retail facilities. In the adult use system, the state issues plant-count limits per licensee, and then the local jurisdiction can impose additional constraints. At the state level, each applicant receives an upper-limit for the number of plants that can be cultivated at one time. There are limits to the number of plants allowed per license and the number of adult use cultivation licenses per location. License holders can request a limit increase directly from the state to an adult use cultivation license so long as they can meet certain criteria²⁸, or they can increase their limit by obtaining additional licenses at other physical locations. While each licensee is limited, the state has not imposed a statewide limit for aggregate production.

As of June 2018, medical cultivators must be vertically integrated with medical centers and expand their plant count by signing up patients, each with an assigned plant count.²⁹ The same parallel state/local system described above applies to medical operations. A medical cultivator that is vertically integrated with a processing (MIP) license is capped at 500 plants.

Benefits and Risks of Alternative License Allocation Systems

The study team is frequently asked to explain the benefits and risks associated with different licensing schemes for marijuana cultivation, manufacturing, and retail businesses. The answer depends upon the specific goals set out by the regulatory agent and the type of market in question.

The approach in Colorado does not explicitly limit the number of cultivation licenses, but instead maintains high standards and quality requirements for license applications and ongoing operations. This is a free market-based approach, where the economic factors of price, supply, and demand are used to determine which licensees will ultimately succeed or fail over time. In most cases, the market-based approach is desirable because it helps identify winners and losers through competition without costly and sometimes ill-conceived administrative intervention.

However, because marijuana is a controlled substance and is illegal in other jurisdictions, two unique risks are associated with the current market-based approach for the adult use and medical marijuana licensing process and supply control mechanisms.

First, there is a risk that the unprofitable licensees will engage in noncompliant activity to improve profit margins. The second risk is overcapacity that causes price or quantity volatility in the marketplace. If supply were to rise significantly above demand, it would lead to market price declines. While such price volatility is fairly common in regular agricultural markets, it presents a specific risk to regulators for a controlled substance. In a typical market, there is a single market price (after allowing for transportation), so agricultural businesses cannot “divert” their product at a higher price. But due to legal prohibitions in other states, there are other marijuana markets with much higher prices, which creates incentives for product diversion. This effect is well-known in tobacco markets, where different tax regulations from state to state have led to smuggling operations between low-tax and high-tax states.³⁰

If these risks become a concern for Colorado, one of the alternatives is to begin restricting the number of licenses issued to control total potential output. There are several options for designing license restrictions. In general, the adoption of license restrictions is likely to bring a cost in the form of higher prices and a sharply higher incidence of rent-seeking activities. The flow of economic rents depends upon how a restricted set of licenses is allocated—either among licensees or to the government itself. A secondary concern is that higher-cost licenses and rents will eventually eliminate small and medium enterprises from the market. Only well-funded, large enterprises can afford to compete when there are high up-front costs and license fees. This effect can potentially accelerate the emergence of a “big marijuana” market outcome, which has been identified as a specific concern by drug policy experts in the past.³¹

²⁸ Production management criteria including sales history, plant count utilization rates, and current and future sales contracts. See MED Rule R 506. <https://www.colorado.gov/pacific/sites/default/files/ColoradoRegister.pdf1%20CCRB%20212%20-2%20Retail%20Effective%200202018.pdf>

²⁹ This requirement has been in place since 2010 but will expire in July 2019. The state will then transition to a production management system similar to the adult use market. See House Bill 18-1381. <https://leg.colorado.gov/bills/hb18-1381>.

³⁰ Tax Foundation, Cigarette Taxes and Cigarette Smuggling by State, 2015. <https://taxfoundation.org/cigarette-tax-cigarette-smuggling-2015/>

³¹ New England Journal of Medicine, Vol. 371 No. 5, Big Marijuana—Lessons from Big Tobacco. <https://www.nejm.org/doi/full/10.1056/NEJMp1406074>

4.2 PLANT COUNTS AND UTILIZATION RATES

As shown in Table 7 below, total medical and adult use allocation in 2017 was approximately 2.5 million plants. This figure is thought to be inflated because of rule changes that occurred during 2015 and a resulting “no harm approach” taken by the state when slotting existing adult use cultivations into a new plant count tier system.³² Upon license renewal in future time periods, the utilization rate—defined as actual plant number usage over allotted plant usage—of these adult use cultivations will be analyzed and adjusted as necessary to reflect the actual utilization of the license. The 2017 utilization rate was 39% at the year-end.

Table 7: Total Plant Allocations and Market-Wide Utilization Rate (2017)

	Total	Medical	Adult Use
2017 Cultivation			
2017 Year End (Actual)	997,842	322,819	675,005
Allocations			
2017 Year End Allowed / Permitted	2,540,536	555,136	1,985,400
Utilization Rate			
2017 Year End	39%	58%	34%
Potential Harvest (Metric Tons)			
Flower Yield	711	155	556
Trim Yield	142	31	111
Total Material	853	186	667

Source: Study team calculations using state harvest and license data.

Some licensees use almost all their allotted plant counts (90%-100%), while others use very little or none of these allocations (0%-10%). In 2017, utilization rates were 1.7 times higher for medical licensees, at 58%, compared to adult use licensees, at 34%. Nine percent of license holders who obtained their state-level cultivation permits did not use them at all. Some of these license holders may be waiting for local-level approval before they can begin operations. Others may be holding permits speculatively, in case they become more valuable as they become scarce or more difficult to obtain in the future.

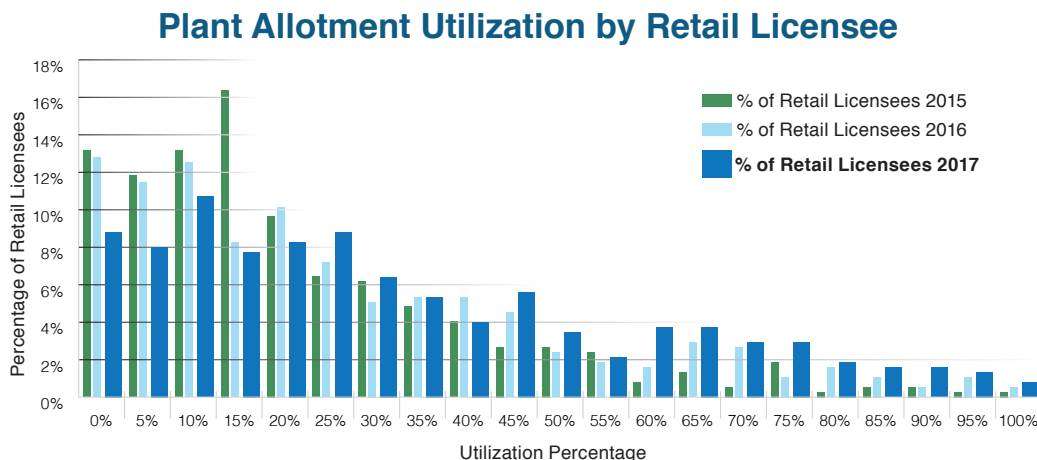
Using statewide totals, the study team calculates the average yield per plant per harvest at 70 grams of flower, plus 14 grams of trim (2.47 ounces flower, 0.49 ounces trim). Using this yield estimate and assuming four harvests per year, we find the total potential market supply was equal to 853 metric tons at the end of 2017. At the current rate of utilization (39%), Colorado cultivators produced a total of 340.7 metric tons of marijuana flower equivalent according to the state’s inventory tracking data.

³² The MED collapsed multiple licenses at a single address and allowed a licensee to keep the aggregate sum of the maximum plant count rather than forcing them to reduce the maximum authorized at a single address. This allowed licensees who had made business plans based on the original understanding of their maximum plant count to be unaffected.

Plant Count Utilization – By Licensee

To further understand allocation, results are presented by adult use cultivation licensee. This is shown in Figure 16 below.

Figure 16: Plant Count Utilization Rates for Colorado Adult Use Licensees - Organized into Histogram Bins (2015 - 2017)



Source: Study team calculations using state harvest and license data.

Figure 16 shows that most adult use cultivation licenses are less than 50% utilized and that about 9% of licensees did not cultivate any plants in 2017. As stated above, this may be related to timing as state licenses must be issued before local licenses, so that some operators may not have had local authority to start growing. If this is indeed the case, and more licensees will begin cultivating as soon as they receive local approvals, there will be increased supply in the Colorado marketplace, leading to more intense price competition and a potential for excess supply for 2018 and beyond. An additional consideration with the number of cultivation licenses issued is the possibility, and likelihood, that some operations exit the marketplace due to competition and inability to remain financially viable. Therefore, any concern over cultivation license utilization rates may be less pronounced, assuming a declining number of cultivation operations in the state.

4.3 MARKET CONCENTRATION AND CONSOLIDATION

For some drug policy experts, an emerging concern in the marijuana literature is the potential for “Big Marijuana” to emerge. This moniker describes the potential consolidation of the marijuana market until just a few, large entities exist that grow, manufacture, and distribute marijuana throughout the state or in multiple states. A fear of Big Marijuana is the potential that a large entity can exert strong lobbying pressure upon the government, in the mold of the tobacco industry in the 1960s and 1970s. These entities would be expected to encourage consumption of marijuana, especially among the heaviest consumers, which could lead to increased dependence and the potential problems associated with the heavy use of the drug.³³ Colorado market consolidation has never been explicitly researched, although local news outlets have begun to identify the largest operators in Colorado in terms of license ownership.³⁴

After connecting a number of licensees with owners and sales reports, the study team found that in Colorado, the largest 10 operators accounted for 26.6 percent of total market sales in 2015, 25.4 percent of total market sales in 2016, and 23.1 percent of total market sales in 2017.

Measuring Market Concentration

³³ New England Journal of Medicine, Vol. 371 No. 5, Big Marijuana—Lessons from Big Tobacco. <https://www.nejm.org/doi/full/10.1056/NEJMp1406074>

³⁴ See, for example, Denver Post, <http://www.denverpost.com/2016/05/07/for-the-first-time-we-know-who-is-behind-denvers-pot-industry/>.

The study team reviewed officially reported sales and organized them by licensee. The sales structure by licensee can be viewed in cohorts, where each \$100 million of sales is allocated to licensees, and then sorted from largest to smallest. The largest 7 licensees account for the first \$100 million, while the smallest 260 licensees account for the last \$39.5 million. This is shown in Table 8 below.

Table 8: Number of Firms per \$100 Million in 2017 Sales, and Average Sales Value per Firm

Firm-Size	# of Firms	Avg. Sales Value	Total Sales*
Largest	7	\$14,280,921	\$100,000,000
	11	\$9,244,682	\$100,000,000
	14	\$7,395,584	\$100,000,000
	16	\$5,980,234	\$100,000,000
	20	\$5,039,228	\$100,000,000
	23	\$4,286,195	\$100,000,000
	28	\$3,647,224	\$100,000,000
	32	\$3,137,320	\$100,000,000
	35	\$2,805,359	\$100,000,000
	42	\$2,394,142	\$100,000,000
	50	\$1,972,805	\$100,000,000
	62	\$1,614,647	\$100,000,000
	78	\$1,280,900	\$100,000,000
	107	\$934,951	\$100,000,000
	179	\$559,145	\$100,000,000
Smallest	260	\$151,792	\$10,000,000
Totals:	964		\$1,510,000,000

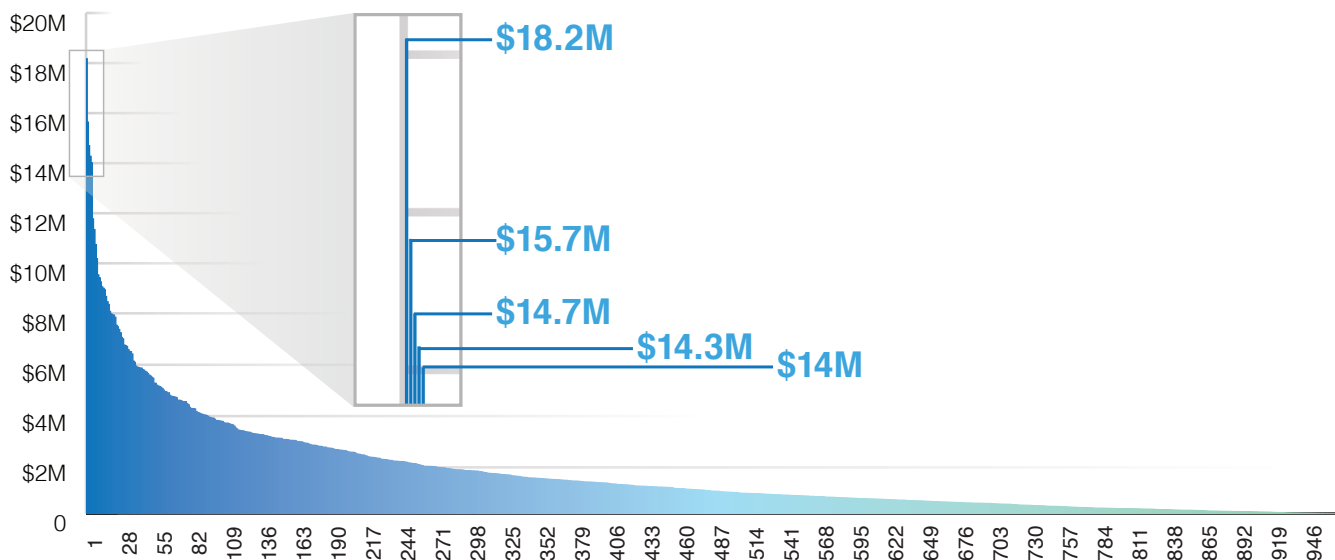
Source: Study team calculations using state sales and license data. Figures are rounded to the nearest \$1 million.

Alternatively, it is possible to apply preexisting metrics for market concentration to Colorado's marijuana marketplace. The best-known indicator of market concentration (or consolidation) is the Herfindahl-Hirschman Index, or HHI, named after economists Orris C. Herfindahl and Albert O. Hirschman.

The HHI provides a summary indication of market consolidation, using a number between 0 and 10,000. A value below 100 indicates that there are numerous competitors with no dominant operators. On the other hand, a value of 10,000 (which is equal to 100²) indicates that the market is organized as a pure monopoly, where one company accounts for 100% of sales. The HHI is the most widely used indicator for competition law and antitrust legal actions.

In order to begin tracking the development of Colorado's market, sales are computed by market type and licensee class. Figure 17 ranks relative sales values by license in Colorado.

Figure 17: Total Sales by License in 2017



Source: Study team calculations using state sales and license data.

As seen in Figure 17, the number of licensees reporting sales of \$1 million or more grew to 451, out of a total of 964 adult use and medical licenses in 2017. Nine licensees had annual sales in excess of \$10 million, with the highest being \$18.2 million.

This information can be tabulated, and then converted into the HHI. The HHI is computed by summing the squared value of each participant's market share. The mathematical formula for the HHI is:

$$H = \sum_{i=1}^N s_i^2$$

Where s is the share of sales for each licensee, among the total number of licensees, N . After summing the squared values for each of the 964 market competitors in Colorado, the HHI index was computed to be 27.6. A value of HHI < 100 indicates a highly competitive marketplace that is contestable. The market is, however, slightly asymmetric, which highlights the broad disparity of sales totals among licensees. The best way to view asymmetry is to compare the number of firms currently competing in the marketplace and compare it to the number of firms that would exist if the market were perfectly symmetric at the same level of HHI competitiveness.

If the market were perfectly symmetric, and the **HHI = 27.6**, then there would be **362 firms**. So, the level of asymmetry in the Colorado market is: $ASY = 964 / 362 = 2.66$. This level of asymmetry suggests that over time, there is likely to be additional consolidation as small companies elect either to exit the market or to be purchased by larger, more efficient operators.

Market Concentration Among Companies

Some have argued that using individual licenses for market shares does not represent the true level of competition, because a single company can own several licenses and brand names. The more licenses that each company owns, the less competition there exists in the market. The challenge faced by researchers is that the state does not currently produce a mapping that links corporate entities or owners with their respective licenses. Each license can be represented using a different company name or brand name, which may be different from the actual owner. In addition, ownership structures across several LLCs within one branded business can differ slightly in their ownership, which complicates the analysis.

In lieu of an explicit table that links owners to licenses, researchers were able to leverage various metadata to approximate the ownership structure in Colorado.

Using the metadata technique, the study team recalculated the HHI by company, rather than by licensee. The corresponding competitiveness index becomes noticeably larger, at $\text{HHI}^{\text{M}} = 100.9$, which is much closer to the threshold of 100 that divides “highly competitive” from “competitive” types of industries. But the value remains well below the threshold of 1,500 defined by the Department of Justice as a “moderately concentrated” industry.

Comparison of HHI Indices

The U.S. Department of Justice (DOJ) has outlined clear guidelines regarding market concentration and its opinion related to how mergers and acquisitions impact the level of market competition. For example, the DOJ and related agencies state in their Guidelines publication that an HHI that is below 1,500 is “unconcentrated.”³⁵ Concentrated markets exist between 1,500 and 2,000 and highly concentrated markets have an HHI = 2,500 or higher.

A brief comparison of HHI indices is shown above in Table 9. Most comparable results were taken from statistics by the United States Census. These figures show that when viewed broadly, a large sector in the United States may appear competitive. For example, the Food Manufacturing Sector has an HHI value of 118, which is considered competitive. But certain subsectors are far more consolidated. Breakfast cereal manufacturers have an HHI of nearly 3,000, which is somewhat anticompetitive, yielding higher prices than a competitive market. Vehicle manufacturing is another consolidated market.

By comparison, the Colorado marijuana market is considered either highly competitive (HHI=27.6) when viewed by licensee or competitive when viewed by holding company (HHI = 100.9). Consolidation is evident over time, as the company HHI has increased between 2014 and 2017 (Figure 18). Further research into the market concentration and pricing of marijuana would be helpful to understand the relative influence of market concentration in marijuana pricing.

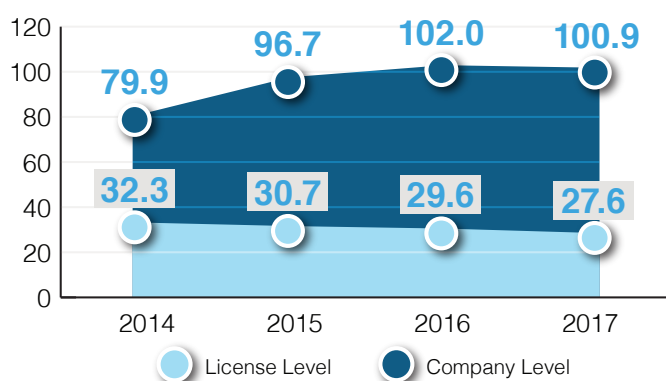
In the geographical analysis presented in Section 3, the pricing data suggest that the number of storefronts (or competition) had a larger influence upon price than the relative share of tourists. At the state level, so far, it appears that average prices are impacted equally by market competition, as well as by relative supply and demand overall. This issue will be revisited in subsequent market assessments for Colorado and elsewhere.

Table 9: Examples of HHI Indexes in Recent Literature

Sector	HHI
Food Manufacturing (sector)	118
Breakfast Cereal Manufacturing	2,999
Motor Vehicle Manufacturing	2,323
Household Furniture Manufacturing	308
Global Beer (2003)	276
Global Beer (2013)	725
Colorado Marijuana Retailing*	28
Colorado Marijuana Companies**	101

Source: Census.gov (1997 & 2012) Source: Study team calculations
 Note: Top 50 firms used for Census Data
 * HHI by licensee
 ** HHI by company
 HHI < 100 indicates highly competitive
 HHI > 2,500 indicates highly concentrated

Figure 18: HHI Index Trends



Source: Study team calculations using state sales and license data.

APPENDIX A: DETAILED RESIDENT CONSUMPTION DERIVATION

Available Data

Several data sources were utilized to estimate the resident marijuana consumption in Colorado. The primary source of data on marijuana use patterns comes from two well established and widely utilized surveys, the National Survey on Drug Use and Health (NSDUH) and the Behavioral Risk Factor Surveillance System (BRFSS).

The NSDUH collects representative state-level data on Colorado marijuana use prevalence, as well as estimates of the frequency of use among current marijuana consumers. NSDUH has been administered each year since 2002, allowing for trend and comparative analysis with other states and the U.S.

The Behavioral Risk Factor Surveillance System (BRFSS) is a nationwide telephone survey that collects state-level data regarding health-related risk behaviors. In 2014, the Colorado BRFSS began collecting data about marijuana use, following the legalization of adult use marijuana in Colorado.

The final survey incorporated in this study is the 2014 Colorado Marijuana Use Survey, completed by the study team. This survey asked Colorado marijuana consumers about their frequency of marijuana consumption, as well as the average quantity consumed on a typical use day. In addition to survey data, this study is the first to utilize transaction-level data from the state inventory tracking system.

These sources are combined with state- and county-level population and demographic data from the American Community Survey and the U.S. Census Bureau.

Resident Consumption Estimation

Total resident consumption in Colorado includes consumption by state residents, and visitors. We consider these market segments separately, first estimating the resident consumption and then the visitor consumption.³⁶ The total Colorado resident consumption is computed using the following formula:

$$D_r = \sum_{t=1}^7 \frac{\text{days}_t \times g_t \times n_t}{1,000,000}$$

where

- D_r = total consumption by adult residents, measured in metric tons of marijuana
- days_t = average number of use days per year for each consumer type 't' (1-365)
- g_t = average number of grams consumed per day for each consumer type 't'
- n_t = total number of people included in each marijuana consumer classification 't'

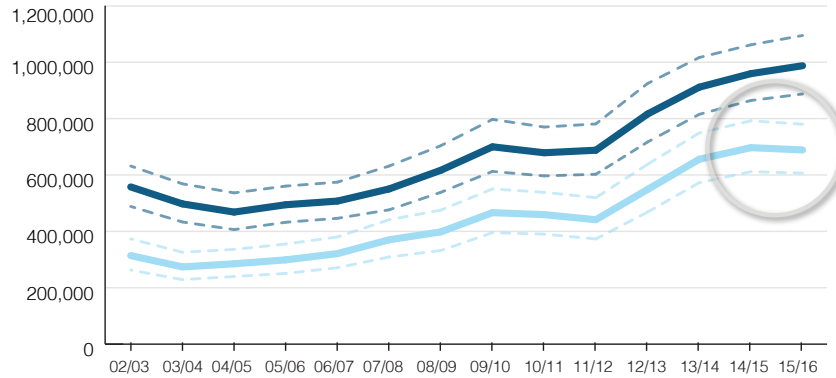
This approach is the most straightforward method to estimate resident consumption since estimates are available (or can be calculated) for each component. The number of marijuana consumers is estimated by combining prevalence data from NSDUH with population data from the ACS. NSDUH also provides estimates of marijuana consumers by type, based on their frequency of consumption, in days. Finally, the average daily consumption quantity for each consumer type is estimated using a combination of recent literature and primary survey data from Colorado residents.

Marijuana Use Prevalence Trends

The figure below illustrates the estimated population of past-year and past-month marijuana consumers in Colorado from the 2002/03 to 2015/16 NSDUH survey results. The solid lines represent the point estimate, while the dotted lines represent the 95% confidence intervals. It is important to note that number of marijuana consumers is also likely to reflect state population growth and immigration, to a degree.

³⁶ See Section 2 for visitor consumption estimation.

Appendix Figure 1: Colorado Past-Year and Past-Month Adult Marijuana Consumers



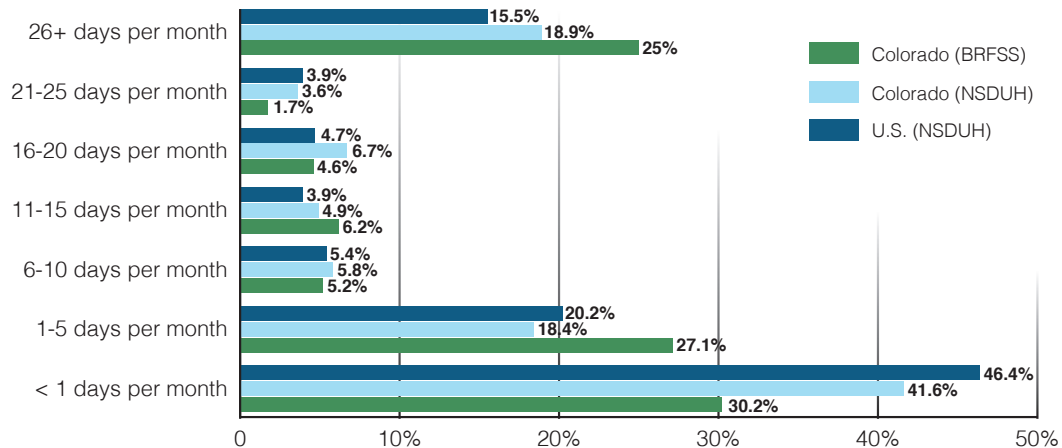
Source: SAMHSA NSDUH. 2002/03-2015/16 Population Estimates.

Beginning in 2014, the Colorado BRFSS survey began asking questions about marijuana use among individuals aged 18 and over. After adjusting survey results³⁷ to reflect the population aged 21 and over, BRFSS data suggests that there were over 551,000 past-month adult marijuana consumers.

Marijuana Use Prevalence

Use prevalence is a commonly used indicator of marijuana use, however the frequency and intensity of marijuana use are also important components of estimating total consumption. Both the NSDUH and BRFSS report the prevalence of marijuana use frequency in seven groups, ranging from 1-5 days of use in the past, to 26 and over days. Marijuana consumers can be classified into three broad categories based on their frequency of use: occasional consumers consume marijuana less than once per month, regular consumers consume between one and 20 days per month, and heavy consumers consume more than 20 days per month. Appendix Figure 2 below compares the 2014 survey estimates³⁸ for Colorado from NSDUH, BRFSS, and compares them to the U.S. NSDUH estimates.

Appendix Figure 2: Frequency of Use Distribution Among Adult Past-Year Marijuana Consumers



Source: SAMHSA NSDUH 2013/14; 2014 Colorado BRFSS.

Appendix Figure 2 reveals that Colorado has a much higher share of “heavy” marijuana consumers compared to the national average. Between 20.3-26.2 percent of the state’s marijuana consumers report near-daily use of marijuana (26 and over days), compared to just 15.5 percent nationwide. At the same

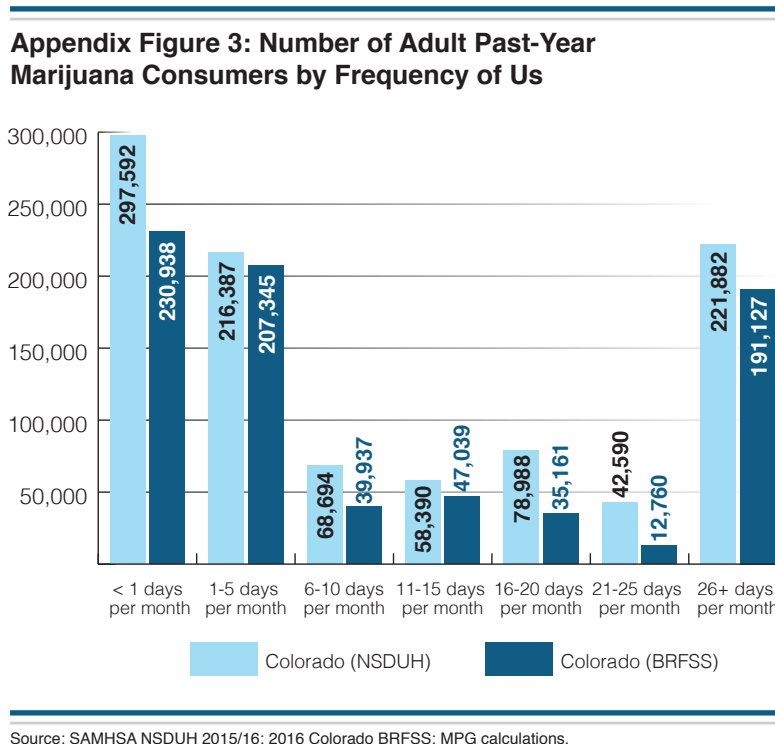
³⁷ Based on U.S. Census data, 5.13% of the Colorado population aged 18 and over is between the ages of 18 and 20. We therefore adjust all BRFSS figures downward by this amount to calculate estimates for those aged 21 and over.

³⁸ Most recent survey year with detail frequency use data publically available for all datasets.

time, the proportion of consumers who reported occasional marijuana use (less than one day per month) is much lower in Colorado (26.8 to 37.3 percent) compared to the national average (46.4 percent).

Updated Population by Days of Use

In order to estimate the number of Colorado consumers in each frequency-of-use cohort, we multiply the Colorado NSDUH and BRFSS prevalence data by data from the U.S. Census Bureau on the state population aged 21 and over. Approximately 985,000 Colorado residents aged 21 and over have consumed marijuana in the past year, which represents about 24 percent of the state's total adult population. About 687,000 or 16.6 percent of the adult population consume marijuana at least once a month. Appendix Figure 3 below shows the estimated population of Colorado marijuana consumers aged 21 and over for each survey source, segmented by frequency of use. The numbers in the figure represent the average of the NSDUH and BRFSS estimates.



Based on the averaged NSDUH and BRFSS estimates, about 265,000 Coloradans report using marijuana less than once per month, while approximately 206,000 residents consume marijuana nearly every day. About 212,000 people used marijuana roughly once per week.

Survey Estimate Adjustments

Historical 2014 survey data has two primary issues that must be accounted for in order to estimate 2017 demand. Since the most recent survey data is from 2015/16, we first adjust estimates of marijuana consumers upwards by 2.03% to account for population growth from 2016 to 2017, as estimated by the State Demography Office.³⁹

Survey data on marijuana is also prone to underreporting for a number of reasons, such as an unwillingness to admit to using a federally illegal substance. In our 2014 study and in this study, we adjust marijuana consumer population estimates for heavy consumers by 11.1 percent and for all other consumer types by 22.2 percent to account for underreporting.

³⁹ <https://demography.dola.colorado.gov/population/data/sya-regions/>

Daily Consumption by Consumer Type

In order to translate the number of adult marijuana consumers into an overall quantity of marijuana demanded, the physical amount of marijuana used by the average consumer on an average use-day must be estimated for each cohort.

In 2014, the study team fielded a survey to collect primary data from Colorado residents about daily use habits. A number of notable results emerged from the survey, but the most important finding for this report is that Colorado resident respondents confirmed the estimated daily consumption quantities from several other studies. The average daily consumption quantities for each consumer type are presented in Appendix Table 1 below.

Appendix Table 1: Quantity Consumed per Use-Day, by Consumer Type

Use Days per Month	Grams per Use Day		
	Lower Bound	Mean Estimate	Upper Bound
<1	0.20	0.30	0.60
1-5	0.43	0.67	0.95
6-10	0.43	0.67	0.95
11-15	0.43	0.67	0.95
16-20	0.43	0.67	0.95
21-25	1.30	1.60	1.90
26-31	1.30	1.60	1.90

Note: Estimates based on Kilmer et al. (2013) and Colorado Marijuana Use Survey results.

As seen in Appendix Table 2, marijuana consumption is estimated at 208.1 metric tons in 2016. As presented in the report (Figure 4), the demand estimate remains virtually unchanged for 2017, at 208.7 metric tons.

Appendix Table 2: 2016 Resident and Visitor Marijuana Use Days and Consumption

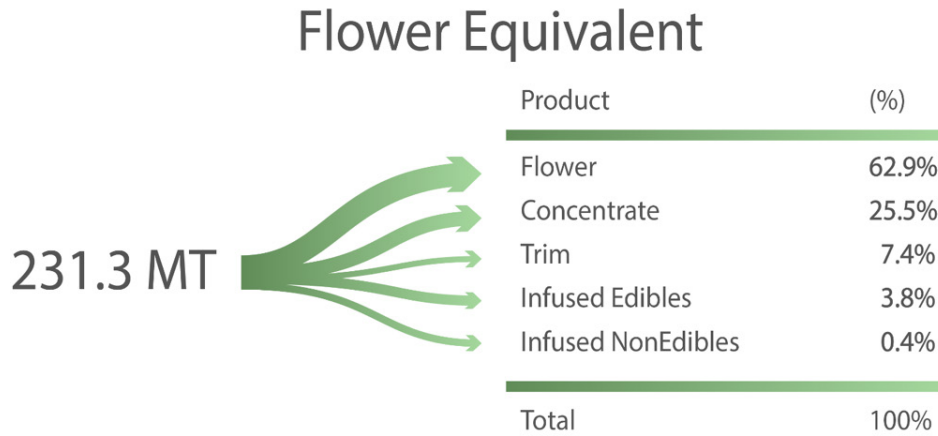
	Residents	Visitors	Total
Adult Marijuana Users	948,739	6,410,620	7,050,359
Annual Marijuana Use Days	149,295,377	17,930,532	167,225,908
Annual Demand (Metric Tons)	190.2	17.9	208.1
Annual Demand (Range)	(148.7 - 234.0)	(13.4 - 22.4)	(162.1 - 256.4)

Source: Study team calculations.

APPENDIX B: SUPPLY-DEMAND BALANCE, FIGURES FOR 2016

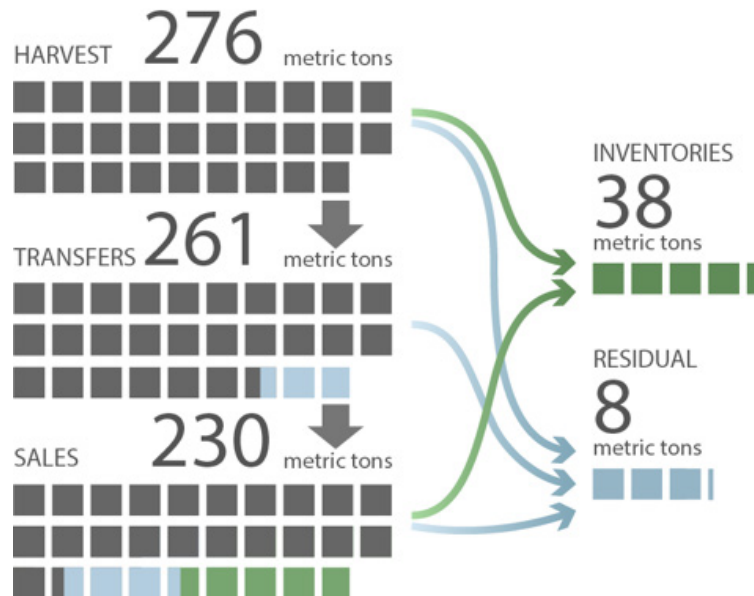
Appendix Figure 3 below shows 231.3 metric tons of flower equivalent sold in Colorado's regulated marijuana market in 2016. In 2017, the amount increased to 301.7 (Figure 3 in report).

Appendix Figure 3: Contributions to 2016 Flower Equivalent Supply Measure – How Different Products Translate into Flower Equivalent Weight.



Source: Study team calculations and methods, using state sales data.

Appendix Figure 4: Estimates of Harvest, Transfers, and Final Sale of Marijuana Products in Colorado - Quantities in Metric Tons of Flower Equivalent



Source: MPG, LLC, State of Colorado

APPENDIX C: GEOGRAPHIC VARIATION IN COLORADO'S MARIJUANA MARKETS FIGURES FOR 2016

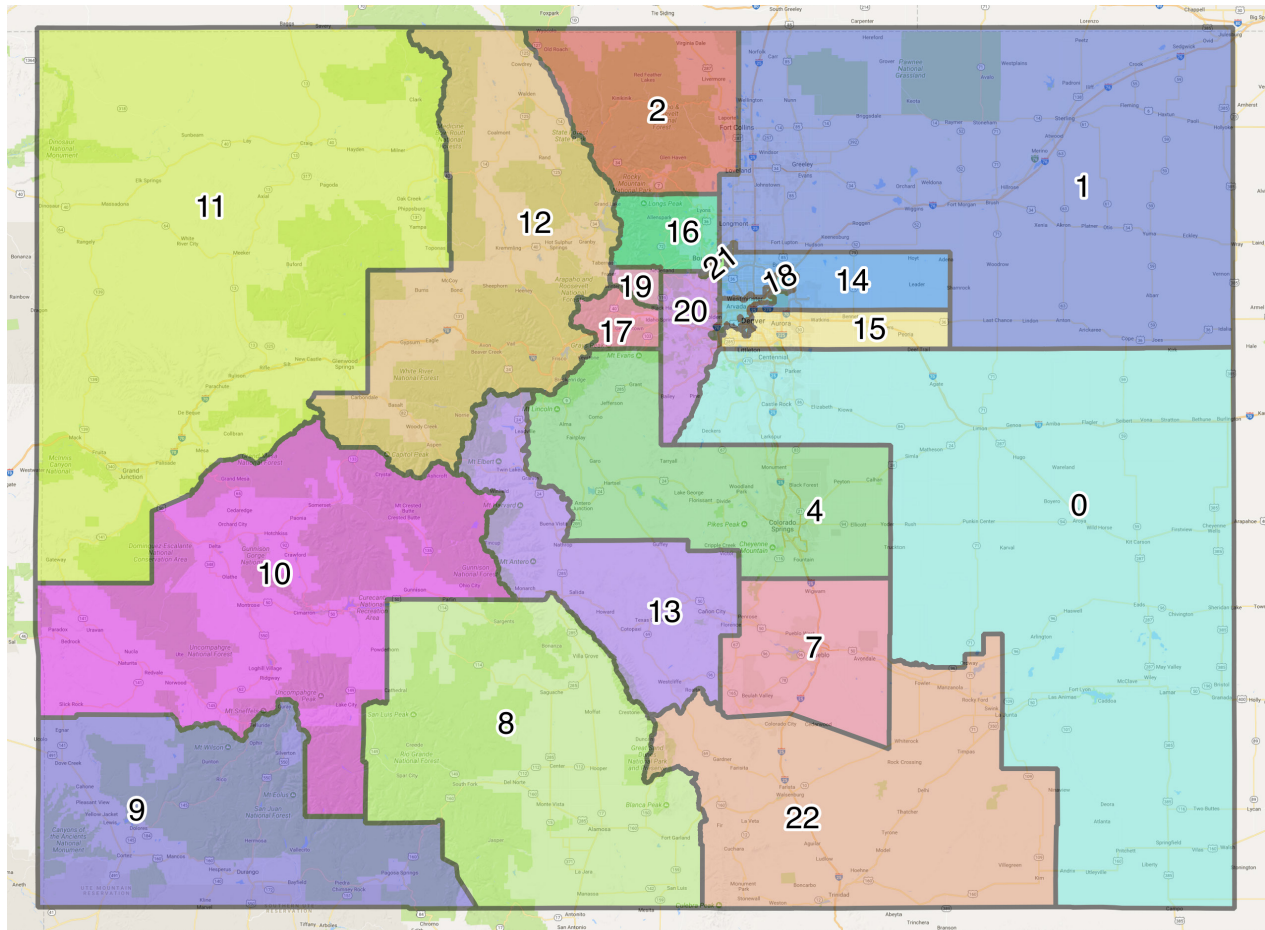
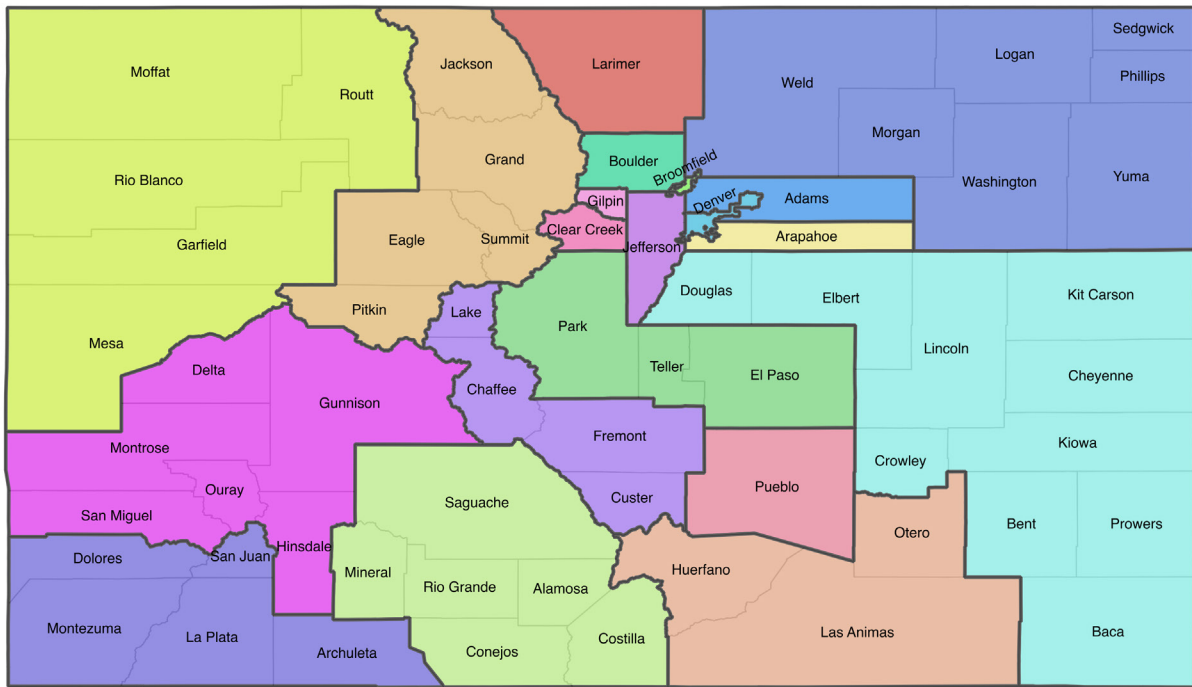
Aggregating Local Medical and Adult Use Marijuana Sales

In order to comply with state taxpayer confidentiality requirements and to provide consistency, the study team aggregates county-level data based on adjustments to the Colorado Planning and Management Regions as defined by the Colorado Department of Local Affairs.^{40,41} Appendix Figure 5 on the following page shows the Colorado counties and corresponding regions. Appendix Figures 6 - 11 are the 2016 counterparts to the geographic maps found in the report.

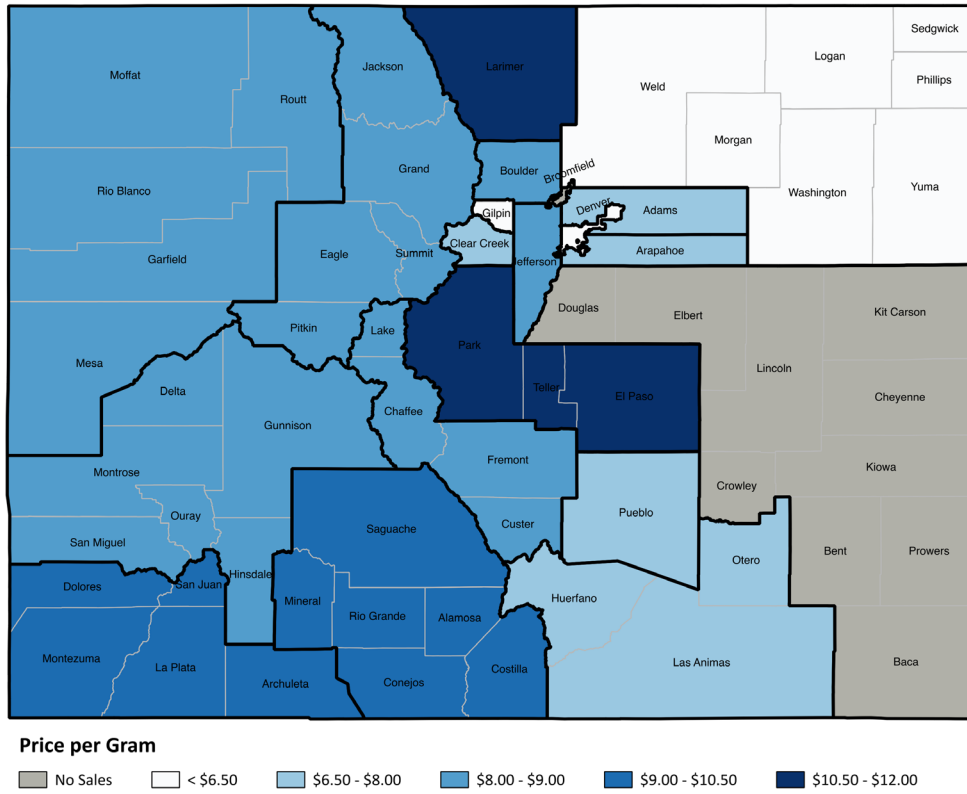
⁴⁰ Under Colorado Revised Statutes §39-21-113(4), any data derived from taxpayer returns must be combined in order to protect the confidentiality of individual taxpayers when there are fewer than three taxpayers in a given category, or any one of them represents more than 80% of the total.

⁴¹ To construct our analytical regions, Weld County is incorporated into Region 1, all counties within Region 3 and Larimer County are presented individually, and Regions 8 and 14 are combined.

Appendix Figure 5. Mapping Regions

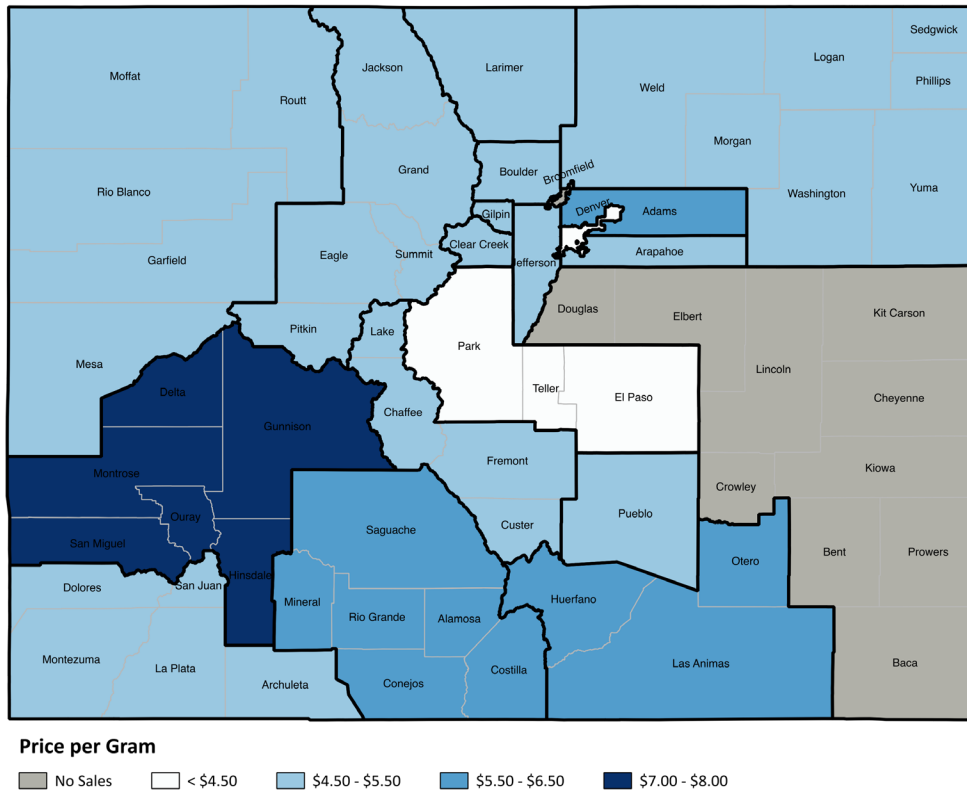


Appendix Figure 6. Adult use Marijuana Flower – Weighted Average Price per Gram, 2016



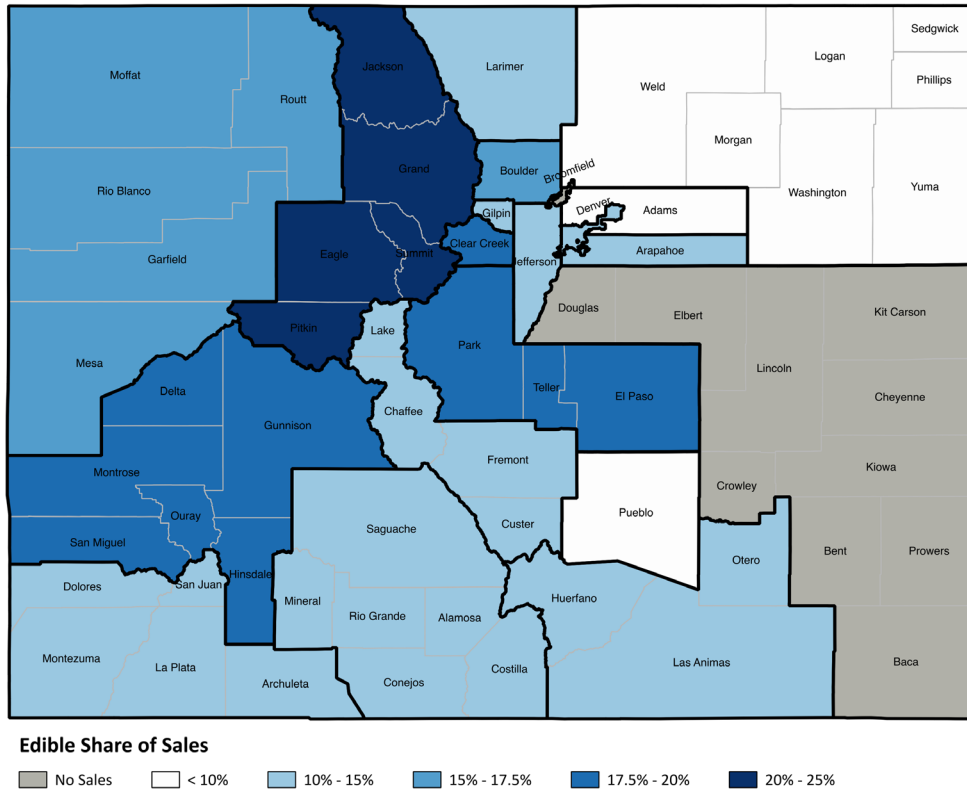
Source: Study team calculations using state sales data.

Appendix Figure 7: Medical Marijuana Flower – Weighted Average Price per Gram, 2016



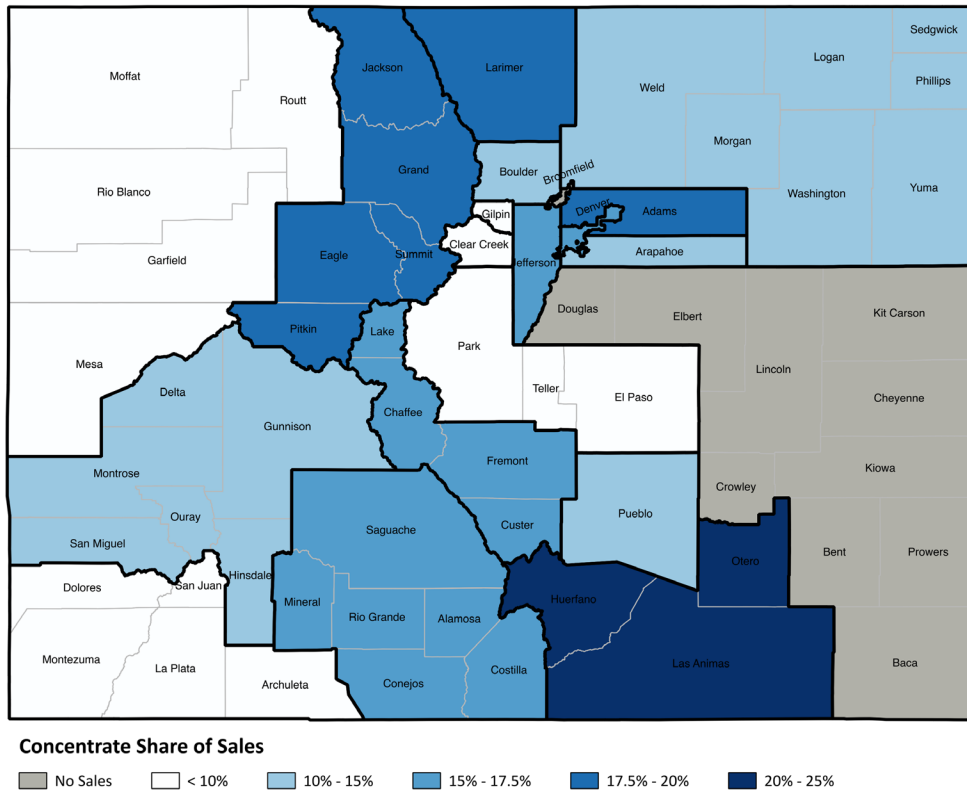
Source: Study team calculations using state sales data.

Appendix Figure 8: Edible Share of Total Sales in Adult Use Market, 2016



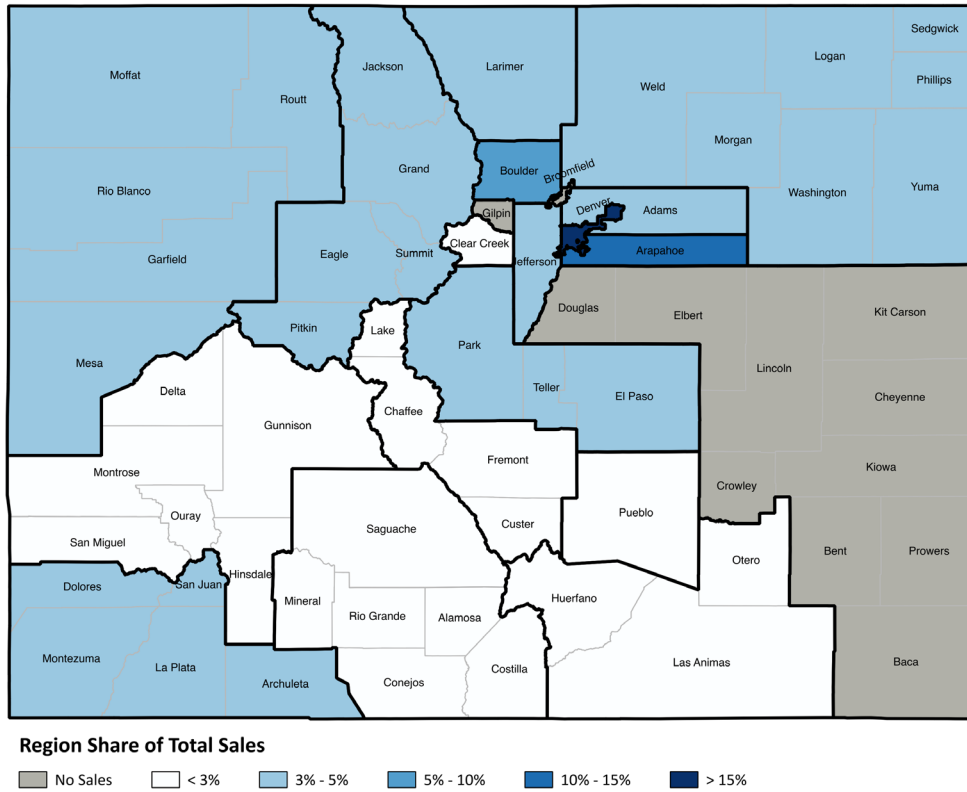
Source: Study team calculations using state sales data.

Appendix Figure 9: Concentrate Share of Total Sales in Adult Use Market, 2016



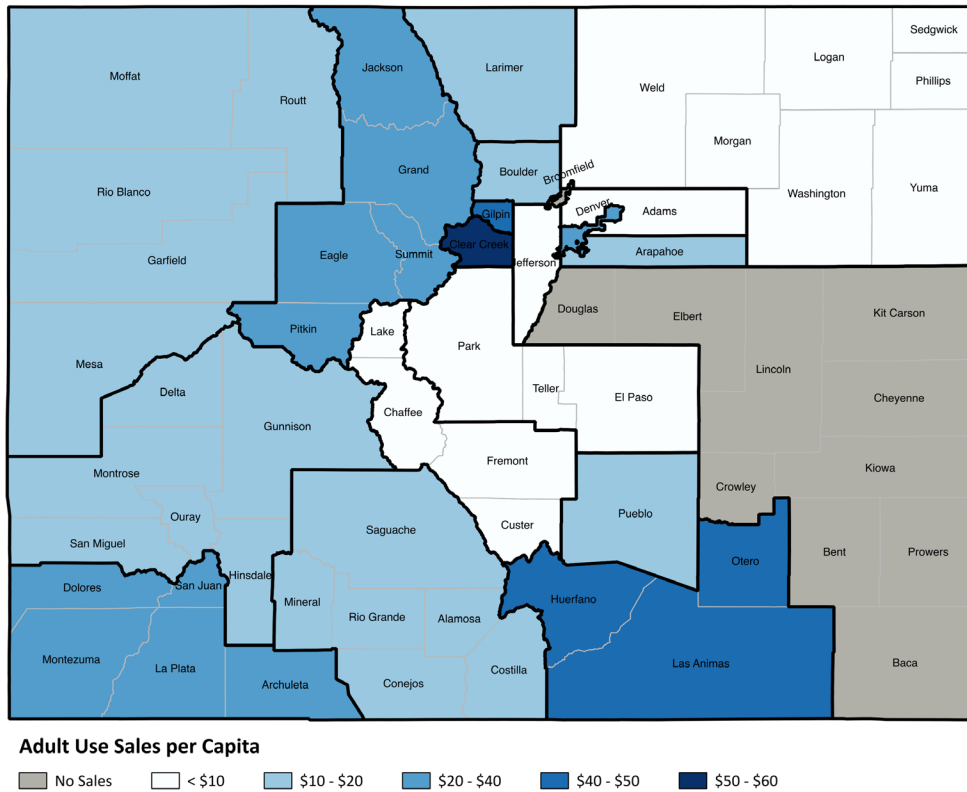
Source: Study team calculations using state sales data.

Appendix Figure 10: Share of Statewide Total Adult Use Sales, 2016



Source: Study team calculations using state sales data.

Appendix Figure 11: Monthly Per Capita Adult Use Sales, 2016



Source: U.S. Census Bureau. Study team calculations using state sales data.

Appendix Table 3: 2016 Pricing for Marijuana Products in Colorado

Market	Colorado	Denver	Boulder	Summit	Eagle
Price per Gram of Flower - 2016 Weighted Average					
Medical	\$4.21	\$3.92	\$4.82	\$5.10	\$4.85
Adult Use	\$7.50	\$5.89	\$8.55	\$8.24	\$8.02
Price per Gram of Concentrate - 2016 Weighted Average					
Medical	\$20.71	\$19.12	\$25.08	\$22.79	\$22.25
Adult Use	\$30.38	\$26.63	\$33.44	\$29.85	\$23.32

APPENDIX EMERGING TOPICS, FIGURES FOR 2016

D:

Appendix Table 4: Total Plant Allocations and Market-wide Utilization Rate -2015

	Total	Medical	Adult use
2015 Cultivation			
2015 Average:	597,803	313,074	284,729
2015 Year End (Actual)	674,881	327,960	346,921
Allocations			
2015 Year End Allowed / Permitted:	1,937,400	629,887	1,307,400
Utilization Rate			
2015 Average:	31%	50%	22%
2015 Year End	35%	52%	27%
Potential Harvest (Metric Tons)			
Flower Yield	542	176	366
Trim Yield	108	35	73
Total Material	650	211	439

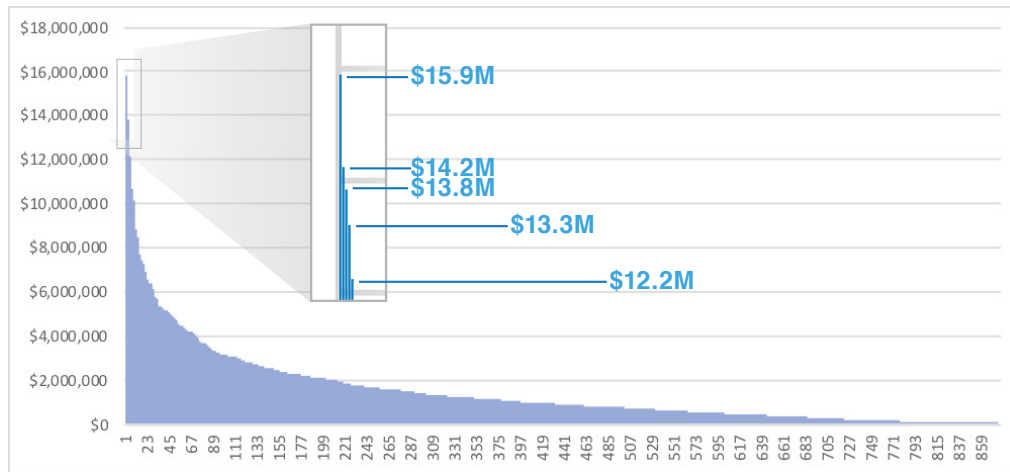
Source: Study team calculations using state harvest and license data.

Appendix Table 5: Total Plant Allocations and Market-wide Utilization Rate -2016

	Total	Medical	Adult Use
2016 Cultivation			
2016 Average:	828,866	343,025	485,841
2016 Year End (Actual)	875,431	350,206	525,225
Allocations			
2016 Year End Allowed / Permitted:	2,085,202	548,002	1,537,200
Utilization Rate			
2016 Average:	40%	63%	32%
2016 Year End	42%	64%	34%
Potential Harvest (Metric Tons)			
Flower Yield	583	153	430
Trim Yield	117	31	86
Total Material	700	184	516

Source: Study team calculations using state harvest and license data.

Appendix Figure 12: Total Sales by License in 2016



Source: Study team calculations using state harvest and license data.

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