

Rulemaking Considerations for Marijuana Production Management in Colorado

Prepared for the Colorado Department of Revenue

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COLORADO
Department of Revenue

The Marijuana Policy Group (MPG) was formed in 2014 as a collaborative effort between the University of Colorado Boulder Business Research Division (www.leeds.colorado.edu/brd) and BBC Research & Consulting (www.bbcresearch.com) in Denver. Both entities have offered custom economic, market, financial and policy research and consulting services for over 40 years. The MPG mission is to apply research methods rooted in economic theory and statistical applications to inform regulatory policy decisions in the rapidly growing legal medical and recreational marijuana markets.

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The Marijuana Policy Group (MPG) presents background and considerations for marijuana production management of marijuana in Colorado; discusses various approaches; and recommends next steps in evaluating production management controls.

Background

The U.S. Department of Justice's priorities and the Colorado Department of Revenue Marijuana Enforcement Division's (MED's) objectives and current marijuana production management approach provide a useful framework for examining production control methods.

"Cole Memorandum." On August 29, 2013, the U.S. Department of Justice Deputy Attorney General James M. Cole released a memorandum to all United States attorneys titled, "Guidance Regarding Marijuana Enforcement." That document identifies marijuana-related enforcement priorities of importance to the federal government:

- Preventing the distribution of marijuana to minors;
- Preventing revenue from the sale of marijuana from going to criminal enterprises, gangs, and cartels;
- Preventing the diversion of marijuana from states where it is legal under state law in some form to other states;
- Preventing state-authorized marijuana activity from being used as a cover or pretext for the trafficking of other illegal drugs or other illegal activity;
- Preventing violence and the use of firearms in the cultivation and distribution of marijuana;
- Preventing drugged driving and the exacerbation of other adverse public health consequences associated with marijuana use;
- Preventing the growing of marijuana on public lands and the attendant public safety and environmental dangers posed by marijuana production on public lands; and
- Preventing marijuana possession or use on federal property.

The Cole Memorandum makes it clear that the Department of Justice expects state and local governments to implement "strong and effective regulatory and enforcement systems" that cover those priorities. A well-designed production management system can, among other effects, minimize or avoid:

- Excess supply, which might lead to diversion of marijuana from Colorado to other states or the unregulated market in Colorado; and
- Possibility of depleted supply of marijuana in Colorado's regulated market, which might lead to an increase in black market activities.

These benefits are in line with the enforcement priorities presented in the Cole Memorandum.

Colorado Department of Revenue "General Principles." The Colorado Department of Revenue Marijuana Enforcement Division's Request for Proposal number DOR14007/MED Study

issued November 13, 2013 stipulated that project deliverables, including the production management system, adhere to the four principles described in Figure 1.

Figure 1.
MED production management system guiding principles

Principle	How principle pertains to	
	MED enforcement	Licensee compliance
Transparent	Open methodologies where the objectives are clear and capable of being replicated in the future	Can fully account for all transactions relevant to the tracking of marijuana
Systematic	Capable of being uniformly applied given current and future data; and Uses current technologies in place at MED	Licensees can utilize State's marijuana inventory tracking system and regulations as a tool to assist in maintaining compliance
Operable	Standards are enforceable; Realistic transition for MED; and Allows for the ability to adjust to market conditions	Can reasonably comply with standards; Realistic transition for licensees; Allows for the ability to adjust to market conditions; and Allows for new entrants into market
Defensible	Grounded in law; Recognized research methods applied; and Able to withstand scientific and legal scrutiny	Licensees who comply with standards can be reasonably assured that MED will find them compliant as well

Source: The Marijuana Policy Group, 2014.

Existing, explicit control measures. The State of Colorado currently uses limits on the number of plants allowable in various segments of the market as a method of controlling the production of marijuana.

Medical marijuana. Colorado's Amendment 20 permits patients to engage in the medical use of marijuana with plant possession limited to:

- Up to six marijuana plants, with three or fewer being mature, flowering plants that are producing a usable form of marijuana; or
- More than six plants if a medical doctor deems a larger quantity to be medically necessary to address the patient's debilitating medical condition and makes such a recommendation to the State.

Medical marijuana patients may grow plants within these limits themselves, or they may assign the plants to a licensed center or a primary caregiver.

Personal use of marijuana. Colorado's Amendment 64 permits persons 21 years of age or older to grow no more than six marijuana plants, with three or fewer being mature, flowering plants.

Retail marijuana. MED adopted a Permanent Rule (R 211(E)) setting an interim production cap on retail marijuana that became effective March 3, 2014. Prior to the MED's intended replacement of this rule in the summer of 2014, this rule limits the allowable number of plants that each retail marijuana cultivation facility and select infused product manufacturers may possess at any one time. Given the limited number of marijuana cultivation facility licenses granted, this rule serves to limit the total amount of marijuana cultivated for the retail market in Colorado.

Retail establishment-level marijuana plant limits include:

- Based upon the Medical Marijuana Center license of the applicant for a Retail Marijuana Store License, Retail Marijuana Cultivation Facility Licenses were limited to cultivations of not more than 3,600 plants (Type 1 Center), 6,000 plants (Type 2 Center), or 10,200 plants (Type 3 Center) in aggregate at any one time; and
- Medical Marijuana-Infused Products Manufacturers with an associated Optional Premises Cultivation were limited to retail marijuana cultivations of not more than 1,000 plants in aggregate at any one time.

The State Licensing Authority, at its sole discretion, may adjust those plant limits on an industry-wide aggregate basis for all establishments subject to that limitation. MED may consider waivers on a case-by-case basis for licensees.

Other regulatory and market factors. There are a number of regulatory and market factors, in addition to the current limits on the number of marijuana plants that can be legally cultivated, that serve to limit supply, including:

- Marijuana produced outside Colorado is prohibited from entering Colorado's regulated market;
- Barriers for new entrants into the retail marijuana market, which include:
 - Licensing;
 - Residency requirements;
 - Capital outlay;
 - Limited personal resources;
- Limited number of local jurisdictions that allow marijuana sales in the regulated market;
- Limited number of new entrants into the market based on local restrictions, such as zoning;
- Additional local restrictions that could further limit new applicants;
- Limited square footage available for cultivations; and

- Barriers for existing cultivations to rapidly scale production.

These factors are integral to a long-term solution to a production management program.

Marijuana Demand Estimates and Actual Marijuana Production

In order to avoid an excess or shortage of marijuana supply and concomitant issues, MED has contracted with the MPG to develop a marijuana demand estimation model that will link with the production management system and identify the appropriate amount of marijuana to be produced by licensed cultivators. The marijuana demand estimation model will provide annual estimates of:

- Medical marijuana demand for dried product (flowers), edibles, and concentrates;
- Retail marijuana demand for flowers, edibles, and concentrates;
- Black and gray market demand for flowers, edibles, and concentrates; and
- Projections of demand growth due to population growth and other factors.

On an annual or more frequent basis, the production management system should allow MED to set marijuana production levels to meet demand for marijuana, potentially at the level of flowers, edibles, and concentrates. As identified in Figure 1 (MED Production Management System Guiding Principles), in order to meet the operability requirement, the selected production control mechanism will need the flexibility to meet changing market conditions and unforeseen fluctuations in demand. That level of flexibility may be difficult to achieve, given the relative inability of cultivators to quickly scale up production and the illegality of diverting any excess product out of the regulated market.

This discussion assumes that, per Amendment 20, medical marijuana will continue to be regulated on a plant basis. Therefore, any alternative production control method would apply only to the retail marijuana market.

As with the production management system, the economic model that estimates marijuana demand will be transparent, systematic, operable, and defensible. The MPG will turn the demand estimation model over to MED, so that MED can update the estimates in the future.

Production Management Options

The MPG examined a number of production management strategies that could apply to retail establishments.

Goals and criteria. The overall goal of a production management system is to ensure that the quantity of marijuana produced is as close as possible to that “legally” demanded in Colorado in order to promote compliance with the enforcement priorities stated in the Cole Memorandum. As previously discussed, it is important that the production management system be transparent, systematic, operable, and defensible.

Additional considerations of any marijuana production management system should include minimizing market distortions of cultivator, retailer, and consumer behavior. Additionally,

consideration should be given to how the production management system influences the concentration of cultivation facility and retail outlet ownership (i.e., are there many small operations or a few very large operations) and whether the resulting outcome is desirable from a policy perspective.

Classification of production management systems. A simple typology of production management system options is to focus on the plant as an intermediate product and divide control measures into three categories:

1. Production inputs to marijuana plants;
2. Marijuana plant count; and
3. Marijuana plant outputs.

Besides discussing these options in the framework of being transparent, systematic, operable, and defensible, it is also important to recognize potentially large differences in enforcement and compliance costs.

Approaches controlling inputs to marijuana plants. For indoor marijuana cultivation operations, there are a number of production inputs that could be limited as a way to control plant yield, including:

- Production area;
- Lighting-related inputs; or
- Nutritional and other environmental inputs.

Other inputs, such as labor or water, fail the operability test to such a degree that they are not discussed here.

In order for any input-based approach to be an effective production management tool, MED will need to estimate the yield of marijuana available per unit of the control measure per year (e.g., yield of marijuana per square foot of canopy per year or yield of marijuana per light hood per year). That estimate is necessary in order to match up input-oriented production controls with the marijuana demand information produced by the MPG that will be provided to MED. Yield estimates may be learned through further research and deliberation with stakeholders.

While some work has gone into estimating the average yield of dried, consumable flowers, there is not much publicly available information about the amount of edibles and concentrates produced per square foot of canopy per year or per light box per year. Over time, Colorado's marijuana inventory tracking system will offer a means to track the production relationships and refine the estimates. Continually tracking production relationships is likely to be necessary as technological or process advancements increase yields or potencies.

Production area. As an example of limiting production area, the Washington State Liquor Control Board (LCB) will limit the actual square footage in licensees' marijuana cultivation facility premises that will be designated as plant canopy. By setting the total amount of canopy for production at approximately two million square feet across all licensees, the LCB intends that

licensed, Washington State marijuana cultivators will produce a known amount of marijuana that is approximately equal to marijuana demand.

As previously discussed, for the production area control measure to meet Colorado MED's operability criterion, MED would have to quantify the amount of flower, edibles, and concentrates produced per square foot of production area per year. MED will also need to craft rules defining what is considered production area and anticipate licensees' potential behaviors to maximize the yield of their allotted production area. There are a number of potential definitions of production areas, ranging from the square footage of canopy of plants that are in the flowering state to the square footage of a licensee's entire facility, which would include bathrooms, offices, and other non-producing spaces.

There is a potential for this production control method to have unintended consequences in how marijuana is cultivated. Under this system, growers would have an incentive to increase plant yields per square foot of canopy, possibly by increasing the height of plants and adapting the lighting structures (e.g., with side lighting). As yields increase per square foot, the State Licensing Authority or MED may need to make downward adjustments to the total number of square feet of cultivation in order to match the supply of marijuana to the demand for marijuana, assuming that demand does not increase at a similar or greater rate. The result may be an inefficient and potentially costly adaptation in the way marijuana is cultivated.

There may be large variations in the yield per square foot per year of plants grown in different environments (i.e., indoor, greenhouse, and outdoor). Yield variations arise from factors such as the number of potential harvests per year (e.g., one harvest per year for outdoor grows versus four to five harvests per year for indoor, hydroponic operations) or the amount of available light. Variations in yield per square foot per year should be understood by MED and, to the extent possible, controlled for and reflected in authorized production allotments.

There are several ways that MED can foster production flexibility within a production area control system. MED should consider mid-year adjustments across all licensees' production area allotments in order to fine tune production. Adjustments might be warranted if the State's marijuana inventory tracking system, and other information indicate that marijuana production is off target or demand is on track to exceed or fall short of expectations. Additionally, MED could provide licensees with as much lead time as possible (e.g., 6 to 12 months) for notifications about allowable increases in production area for the next licensing year. This would provide licensees with adequate time to increase the scale of their operations and help ensure that licensees weren't consistently under-producing relative to their allotment. Careful consideration should be given to the operability of any method used to more finely tune the amount of marijuana produced.

Using square feet of production area as a control measure adds relatively little to MED enforcement costs or licensee compliance costs, assuming that each licensee's square footage allotment could accommodate their existing, plant count-based operations. Licensees already file cultivation facility architectural plans with MED and might be required to further identify the production areas that they are using to stay within limits. MED could regularly check facility operations against approved licensee production areas. MED would also need to keep all aspects

of its current inventory tracking system, including Radio Frequency Identification (RFID) tags on plants, to ensure full accountability of marijuana from seed to sale.

Lighting-related inputs. Marijuana plant yield, up to a point, increases with the careful application of additional light. Given the current lighting hood and light bulb technology that is commercially available and economically viable to cultivation facilities, indoor cultivation facilities grow a fairly consistent number of plants in the vegetative or flowering state per light hood. These hoods often use one to two bulbs in the 300 to 1,000 watt range. Throughout the growing cycle, these hood/light combinations are used at varying intensities (often using differing heights from the plants and different electrical current levels) and periods of the day.

Controlling any of the lighting characteristics in an indoor cultivation facility, from hood size or number of hoods to the number and/or wattage of bulbs to the total power consumption across a period might serve to limit the aggregate yield of marijuana produced in licensed production facilities. A lighting-related control, however, would not be applicable to outdoor cultivation, which would require another control mechanism such as production area or plant count.

Much as with controlling output via limiting production area, there are drawbacks to a production management system that attempts to manage output through lighting-related inputs. While lighting-related controls may be transparent and systematic, there are limits to the operability of these mechanisms:

- **Number of hoods**—any limit to the number of hoods would need to also specify attributes of the hoods, such as size and number of lights. The outcome of this limitation might serve to increase the number of plants per hood below optimum, economically efficient levels and hamper the adoption of new energy saving technologies such as the use of LED lights.
- **Total wattage of installed lights**—limits to the total wattage of lights used would be difficult to audit on a routine basis and might fail as a production control measure if technological advances, such as the adoption of relatively lower wattage LED lights, allowed for much greater production per watt. Additionally, the effectiveness of a light bulb diminishes over time and that effect would reduce the accuracy of yield per watt per year estimates.
- **Total power consumption**—limits to power consumption per year might be easy to circumvent and, as with limiting the wattage of installed lights, might fail if technological advances, such as the adoption of relatively lower wattage LED lights, allowed for much greater production per unit of power consumption.

Additionally, if a lighting-related control measure was used for indoor operations and another mechanism, such as production area, was used for outdoor operations, then it might be difficult to avoid introducing inefficient incentives to towards one type of operation.

Nutritional and other environmental inputs. Many other inputs to production, such as nutrients provided to plants in hydroponic operations, could be limited in an attempt to control yield. However, these mechanisms would fail the operability test and would likely cause inefficient changes in cultivation processes.

Limiting the number of marijuana plants. As previously discussed in this paper, MED currently manages marijuana production via limiting plant counts in the medical and retail marijuana markets. Moving forward, this methodology has the benefit of being a known entity for current marijuana production facility license holders.

As evidenced by the performance of MED's plant count production management method, plant counts meet MED's criteria of being transparent, systematic, operable, and defensible. Unlike issues associated with potential lighting control measures, plant counts can be systematically applied to all cultivation operations, including outdoor grows. Both MED personnel and marijuana cultivators are accustomed to auditing and tracking plant counts, and the State's marijuana inventory tracking system facilitates that accountability. Additionally, many marijuana cultivation facility license holders have designed their facilities and operations around a plant count control measure and might reasonably expect plant count limits to continue.

There are potential distortions that arise from limiting plant counts, such as:

- Increasing potency (primarily average THC levels) in plants;
- Changing the duration of various stages of the seed to harvest process; and
- Driving production toward indoor, hydroponic cultivation methods and away from outdoor operations.

Increasing potency in marijuana plants is a concern of MED and policy makers. However, the long-term trend towards high THC levels evident in marijuana began before Colorado instituted limits on plant counts and may be due to a variety of factors, including consumer demands and a desire by illicit growers to minimize the footprint, weight, or bulkiness of their operations. Additionally, if consumers' demands are THC-focused as opposed to dry weight of product-focused, then the allowable plant count can be reduced if THC levels increase. Alternatively, acceptable THC levels could be capped via statutory means.

Driving production toward indoor operations and away from outdoor operations may provide benefits that are in-line with law enforcement priorities and industry desires. Benefits of indoor cultivations include:

- Plant yield may be more consistent with indoor than with outdoor operations—facilitating more accurate predictions of industry production;
- Indoor cultivations largely remain out-of-sight, which may benefit public acceptance of the industry;
- Regulatory enforcement and licensee compliance may be simplified with indoor operations; and
- A very large outdoor cultivation could cause excess supply and price instability and leave small producers unable to compete.

However, indoor marijuana cultivations are resource intensive and the potential environmental impacts of these operations should be taken into consideration.

As with the production area control measure (e.g., limiting the square feet of marijuana plant canopy), for the plant count control measure to meet MED's operability criterion, MED would have to quantify the amount of flower, edibles, and concentrates produced per plant per year. There may be large variations in the yield per plant per year of different marijuana strains and of plants grown in different environments (i.e., indoor, greenhouse, and outdoor). Yield variations arise from factors such as number of potential harvests per year (e.g., one harvest per year for outdoor grows versus four to five harvests per year for indoor, hydroponic operations). Variations in yield per plant per year should be understood by MED and, to the extent possible, controlled for and reflected in authorized production allotments. The State's marijuana inventory tracking system will offer a way to accurately track yield while controlling for a number of causal factors.

There are several ways that MED can foster production flexibility within a plant count control system. MED should consider mid-year adjustments across all licensees' plant count allotments in order to fine tune production. Adjustments might be warranted if the State's marijuana inventory tracking system and other information indicate that marijuana production is off target or demand is on track to exceed or fall short of expectations. Additionally, MED could provide licensees with as much lead time as possible (e.g., 6 to 12 months) for notifications about allowable increases in plant counts for the next licensing year. This would provide licensees with adequate time to increase the scale of their operations and help ensure that licensees weren't consistently under-producing relative to their allotment. Careful consideration should be given to the operability of any method used to more finely tune the amount of marijuana produced.

There is no additional burden to MED enforcement or licensee compliance if MED chooses to remain with plant count as a production control method.

Approaches controlling marijuana outputs. From the standpoint of accurately matching marijuana supplies to Colorado market demands, using an output production control method matched as closely as possible to the bundle of marijuana attributes demanded by consumers might be optimal. Output controls to consider might include:

- Weight of finished product;
- Weight of finished product with option for additional production credits;
- Amount of THC; and
- Amount of effective THC.

Weight of finished product. A very common way for marijuana consumers to think about and purchase marijuana is by weight. The MED marijuana demand model also uses a dry weight measure to quantify demand of flowers. The lack of necessary estimations about plant yields per year or yield per square foot of canopy per year would seem to make dry weight produced an appealing production control option relative to an input or plant count option.

Using finished product per unit of time as a control measure should meet MED's criteria of being transparent, systematic, and defensible. However, the operability of using a finished product control measure is potentially more complex than the operability of using a plant count or

square footage of production area control measure. While MED can use the State’s marijuana inventory tracking system functionality to track and control cultivation facility output, much of the onus of accurately projecting the finished product yield of a grow operation would be borne by the licensee. Implementation considerations of a finished product control measure include:

- Length of production control cycle (e.g., semiannual or annual);
- Point in the seed to sale process where finished product is measured and limited;
- Limiting inventory buildups at the end of a production period for cultivators that grew too much;
- Potential to have uneven production across the time period;
- Controlling production of edibles and concentrates; and
- Fostering flexibility to ensure adequate, but not excessive, marijuana supply.

The need to control potential inventory build-ups is a very important consideration. For example, if the control measure were placed at the wholesale transaction level (i.e., a “package” of marijuana can only be moved out of a cultivation facility if the licensee has not yet met their production limit for the period), then it is possible that any licensee with production in excess of their authorized limit in one period would build inventory of finished product (or intermediate product for trim and sugar leaf) until the next control period begins. If there is variation in potential crop yield levels, then there may actually be an incentive for a licensee to slightly exceed their authorized production limit—as the licensee would lose profits if they under-produced and could simply build inventory for a short time if they over-produced. Any inventory buildups would need to be carefully monitored and tightly controlled to avoid diversion into the unregulated market.

Additionally, if demand is unexpectedly high in a control period, there may be market disruptions towards the end of a control period if a substantial number of licensees are on the same production control schedule and have reached their quota at the same time. That market disruption would be needless if some portion of those licensees had excess inventory that they were not legally permitted to move into the retail market. One potential drawback of such a disruption would be market shortages and price spikes—both of which might increase the demand for marijuana produced in the unregulated (i.e. black or gray) market. Further, if licensees had excess inventory at the end of one control period that they then released at the beginning of the following control period, this might cause undesirable price declines. The degree to which licensees are on different production control cycles (e.g., each licensee’s cycle could be concurrent with their license renewal period) could serve to mitigate this potential market disruption.

For comparison, such potential market disruptions would be mitigated if MED used a production area (i.e., square feet) or plant count production control measure. That mitigation would occur because production would be fairly constant across a year (assuming that almost all cultivations remained indoors) as licensees would have no limit on the amount of finished product they could produce in a year with their licensed number of square feet or plants.

MED could take one of several approaches to including edibles and concentrates in a finished product control measure:

- MED could develop an equivalency measure between trim/sugar leaf (the primary inputs in concentrates and edibles) and flowers and apply it at the cultivator level. If, for example, a pound of trim/sugar leaf was determined to be equivalent to half a pound of flowers, then the overall production limit could be expressed as weight of finished flowers and this ratio applied as a conversion. The benefit of this approach is that it would allow MED to control production at the cultivator level. The primary difficulty of this approach is developing the equivalency measure, as obvious measures such as wholesale price differences or THC content differences may not be apparent due to vertical integration of the cultivators and retail establishments and lack of adequate and uniform testing. As testing improves and non-vertically integrated cultivators arise, it should be possible to refine the equivalency measure.
- Once THC testing of concentrates and edibles ramps up in late 2014, MED could develop a THC equivalency between these products and finished flowers at the item level. A primary consideration with this approach would be where in the seed to sale process the production limit is placed. In the case where cultivators wholesale flowers directly to retail establishments and wholesale the trim and sugar leaf to marijuana infused-product manufacturers (who then wholesale concentrates and edibles to retail establishments), it will be operationally difficult to include the finished products in a control limit on cultivators.

There are several ways that MED can foster production flexibility within a finished product control system. MED should consider mid-year adjustments across all licensees' finished product allotments in order to fine tune production. Adjustments might be warranted if the State's marijuana inventory tracking system and other information indicate that marijuana production is off target or demand is on track to exceed or fall short of expectations. Additionally, MED could provide licensees with as much lead time as possible (e.g., 6 to 12 months) for notifications about allowable increases in production limits for the next licensing year. This would provide licensees with adequate time to increase the scale of their operations and help ensure that licensees weren't consistently under-producing relative to their allotment. A further method to increase flexibility is to allow the purchase of additional production credits. Careful consideration should be given to the operability of any method used to more finely tune the amount of marijuana produced.

Weight of finished product with option for additional production credits. One potential solution to some of the issues (e.g., inventory buildup and the need for production level flexibility) with a finished product limitation is to allow licensees to purchase additional production credits if they met certain criteria. This system would have several benefits, including:

- Licensees could potentially avoid building inventory at the end of a production control period;
- Unexpected increases in demand or variations in production could be accommodated; and

- MED could vary the price of additional production credits in the middle of a control period to signal producers to either ramp up production (low price) or not exceed their original limits (high price).

Instead of explicitly setting the price of excess marijuana production credits, MED could set up an auction and let licensees determine how much the credits would be worth to them.

Regardless of how MED chooses to determine the appropriate price of excess production credits, MED should carefully consider:

- Whether to allow licensees to trade excess production credits between themselves;
- Whether and how to limit speculation in credits;
- Potential excess credit purchase limits to make sure that purchasers of credits don't vastly overproduce;
- How best to limit inventory buildup at the licensed retail establishment level, particularly in an environment where some cultivators are vertically integrated with retail establishments; and
- Other criteria to make sure that the excess production credits fulfill their intended purpose (e.g., that a producer must have sold a large portion of their existing allotment and have a demonstrable demand for their excess production).

While an excess production credit mechanism mitigates some of the issues of a finished product control method, the MED enforcement costs and licensee compliance costs would be higher than either a plant count or production area control mechanism.

Amount of THC. Another potential control measure, which might correspond well to one of the core reasons for marijuana consumption, would be to limit the total amount of THC produced in any period. Given the already relatively high potency of marijuana, the potential to circumvent some production control mechanisms by further increasing THC levels, and discussion in Colorado about limiting THC levels, a THC-based production control mechanism might be considered. Regarding the MED criteria for a viable production control mechanism, a THC-based approach is likely transparent, systematic, and defensible and may have the lowest potential for circumvention and unwanted distortions on production.

However, a THC-based approach has the same implementation considerations of a finished product approach:

- Length of production control cycle (e.g., semiannual or annual);
- Point in the seed to sale process where THC is measured and limited;
- Limiting inventory buildups at the end of a production period for cultivators that exceeded their total THC allotment;
- Potential to have uneven production across the time period;
- Controlling production of edibles and flowers; and
- Fostering flexibility to ensure adequate, but not excessive, marijuana supply.

Additionally, adoption of a THC-based production management approach is not possible until THC testing is refined and implemented on an extensive scale. Accurately quantifying the total amount of THC produced in a period will also require a THC testing approach that produces statistically valid THC concentration estimates for:

- Flowers, potentially at the plant level given the variety of plant genetics and the differing environmental conditions under which plants are grown;
- Concentrates at the production batch level; and
- Edibles at the production batch level.

THC levels also degrade across time and under different environmental conditions, which might need to be taken into account.

Consideration must also be given to converting dry product weight-based demand estimates from the MED demand model into a quantity of THC demanded. Because marijuana consumers typically do not know the weight of THC they consumed in a period, and because none of the survey-based data that serve as inputs to the MED demand model are measured in THC levels, either a new survey effort will need to be undertaken or MED will need to estimate average THC levels in consumed marijuana—potentially introducing a source of error.

Of all the possible production control methods, using a THC-based production management approach is perhaps the least likely to introduce unwanted distortions into the seed to sale process. For example, there would be no incentive to increase THC levels in plants solely to drive up revenue per plant. Each licensee would instead determine in what way they would produce their allotted THC amount, using as many or as few plants as desired and growing these plants in a way that best serves customer demands.

Amount of effective THC. There are many active compounds in marijuana besides THC—the primary psychoactive compound. Other cannabinoids in marijuana, such as cannabidiol (CBD), cannabinol (CBN), and tetrahydrocannabinol (THCV), also have desired medicinal and recreational effects and some of these cannabinoids (especially CBD) may serve to buffer THC’s psychoactive effects. As such, from a policy standpoint it may be worth considering incentives that drive cultivators to increase the CBD-to-THC ratio in their finished product.

A potential production control measure that may serve to increase CBD-to-THC ratios and provide downward pressure on THC potency would be to define and control an “effective THC” measure that would simultaneously limit THC production and attempt to incentivize higher CBD (or other cannabinoid)-to-THC ratios. Kleiman (2013) proposed consideration of this approach in a paper for the Washington State Liquor Control Board titled, “Alternative Bases for Limiting Cannabis Production.”

An example of a potential option for defining effective THC might be to subtract some factor of CBD weight from THC weight. Marijuana cultivators, attempting to maximize profits and remain within the effective THC control limits, may then select a different mix of marijuana plant strains or alter the growing environment in such a way as to produce marijuana with lower THC levels and higher CBD (or other cannabinoid) levels.

An effective THC production control method would have the same operational complexities as described above in limiting the amount of THC—primarily that the testing accuracy for THC and CBD and the associated testing industry is not yet established. Additionally, the defensibility of this approach may be relatively lower than other potential production control methods—at least until additional medical studies of THC and other cannabinoids are completed.

Summary

All of the production control methods discussed here would likely meet the MED criteria of being transparent and all but lighting-related inputs, which would apply only to indoor grow operations, would meet the criteria of being systematic. As shown in Figure 2 and previously discussed, only the production area, plant count, and dry weight production control methods currently meet both the criteria of being operable and defensible. Once testing procedures are well established, THC- and effective THC-based methods would likely be operable. It is unknown whether the scientific evidence about effective THC and any potential policy benefits would meet MED’s criterion of being defensible.

Figure 2.
Characteristics of various production control methods

Production Control Method	MED Criteria			
	<i>Transparent</i>	<i>Systematic</i>	<i>Operable</i>	<i>Defensible</i>
Input-related methods				
Production area	Yes	Yes	Yes	Yes
Lighting-related inputs	Yes	No	Difficult	Questionable
Nutritional inputs	Yes	Yes	No	No
Plant count	Yes	Yes	Yes	Yes
Output-related methods				
Finished product	Yes	Yes	Yes	Yes
Finished product with option	Yes	Yes	Yes	Yes
THC	Yes	Yes	In future?	Yes
Effective THC	Yes	Yes	In future?	Unknown

Source: The Marijuana Policy Group, 2014.

As part of examining operability, the MPG compared the level of enforcement and compliance efforts of different control measures relative to the plant count measure that is currently in place in Colorado. Figure 3 summarizes this information and also indicates the potential for market distortions that could arise from each production control alternative.

Figure 3.
Comparison of enforcement and compliance burdens and potential distortions

Production Control Method	Level of effort relative to plant count controls		Potential for Market Distortions
	<i>MED Enforcement</i>	<i>Licensee Compliance</i>	
Input-related methods			
Production area	Slightly higher	Slightly higher	Moderate
Lighting-related inputs	Higher	Higher	High
Nutritional inputs	Much higher	Much higher	High
Plant count	Same	Same	Moderate
Output-related methods			
Finished product	Slightly higher	Higher	Moderate
Finished product with option	Higher	Higher	Moderate
THC	Higher	Higher	Very low
Effective THC	Higher	Higher	Very low

Source: The Marijuana Policy Group, 2014.

MED enforcement and licensee compliance costs would likely increase, at least slightly, under any alternative control method relative to a plant count limitation. A production area limitation, due to its similarity to the plant count limitation, would likely have the least additional burden. While the finished product options have a reasonable burden for MED enforcement, careful consideration should be given to whether cultivators are able to adequately anticipate the final yield of their operation across a year. It seems likely that the least sophisticated growers will not be able to make adequately accurate yield projections, which may have a number of negative side effects.

The MPG expects the potential for cultivator behavior distortions would range from very low for THC- and effective-THC based production control approaches to high for control of lighting-related or nutritional inputs. Plant count, production area, and dry weight production control approaches would each have a moderate potential to distort cultivator behavior.

Each production control measure discussed in this paper would require one or more estimations in order to be operable by MED and licensees. All production control measures except the THC-based control measures would require an estimate of edible and concentrate yields relative to flower yields, and an estimate of the average dry weight yield per control measure unit. THC-based control measures would require an estimate of the average THC content of finished flowers, edibles and concentrates. Figure 4 provides this information.

Figure 4.
Estimations required for various production control methods

Production Control Method	Edible or concentrate conversion	Average dry weight yield			Avg. THC content of marijuana
		per sqft canopy	per unit lighting	per unit nutrition	
Input-related methods					
Production area	X	X			
Lighting-related inputs	X		X		
Nutritional inputs	X			X	
Plant count	X				X
Output-related methods					
Finished product	X				
Finished product with option	X				
THC					X
Effective THC					X

Source: The Marijuana Policy Group, 2014.

The required estimates shown in Figure 4 are all averages that would need to be calculated across a statistically valid sample of consumers or producers. When selecting a control method, it will be important to consider at least two factors about these estimates.

First, trends in marijuana consumption (e.g., the increasing use of concentrates, such as butane hash oil) may affect the stability of some estimates or increase the adverse effects of any estimation errors. Less stable estimates or larger error bounds around the estimate may decrease the desirability of control methods that rely on that estimation.

Second, all else equal, it may be preferable to select a control mechanism with a smaller variance in dry weight yield per unit or average THC content per unit. A small variance on the producer side estimate might indicate a control method that is less likely to shift quickly (e.g., though technology improvements) or to favor some producers (e.g., those with high yield per plant) over others.

Recommendations

There are three viable production control mechanisms for the retail market that largely meet MED’s criteria of being transparent, systematic, operable, and defensible:

- Production area;
- Plant count; and
- Weight/units of finished product (with or without the excess credit option).

MED should carefully consider the operability, potential market distortions, MED enforcement burden, and licensee compliance burden when selecting between these three mechanisms.

Because the production area and plant count mechanisms are very similar in their operability, MED should consider the degree to which:

- Cultivators and other market participants have designed their business processes around meeting a plant count limitation;
- Shifting from a plant count limitation to a production area limitation might be disruptive to MED personnel, the State’s marijuana inventory tracking system implementation, and the cultivators and other market participants; and
- The benefits, if any, of shifting to a production area limitation outweigh the perceived costs.

As previously discussed, MED should also strongly consider market trends, advances in production technology, and the variance in yield per plant versus the variance in yield per square foot of production area when selecting between plant count and production area methods. For example, if there is a more consistent yield per square foot of canopy across cultivators than there is per plant, then MED might favor a production area control.

In order to select between production area/plant count and finished product mechanism, MED should consider whether:

- MED can accurately predict yield per square foot of production area per year or yield per plant per year;
- MED can control edibles and concentrates in a finished product mechanism by controlling trim/sugar leaf (and potentially fan leaf) at the cultivator level;
- The benefits of a finished product model outweigh this approach’s additional operability complexities and regulatory burdens over a production area/plant count approach.

Regardless of which of these available production control mechanisms that MED selects, MED should carefully track trends in the average THC content of marketable product to determine whether increased potency is being used by licensees to circumvent the control measure. If marijuana potency does increase, then MED should, at a minimum, adjust the market demand levels downward and therefore reduce allowable plant count, production area, or amount of finished product. Once an adequate THC testing system is in place, if marijuana potency increases then MED should evaluate the feasibility of moving to a THC-based limitation. Similarly, if the consumer trend towards purchasing concentrates continues, MED should also consider moving to a THC-based limitation.

The CU/BBC team recommends that MED keep all current inventory tracking systems in place—especially using RFID tags at the plant level. Given variability in plant or canopy yield and THC content across different licensees, there will continue to be a potential for marijuana diversion between harvest and packaging. The State’s marijuana inventory tracking system, as it is currently implemented, will allow MED to identify potential problems with a cultivator and determine the cause and whether action is appropriate. MED should consider refinements to the marijuana inventory tracking system, including adding additional data fields, to facilitate marijuana tracking, MED enforcement activities, and licensee compliance.

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