Summary of Methodologies

1.A: Estimating Production

Data Sources

The main data sources used for the THC production analysis are listed in Table 1.A.1.

Table 1.A.1 Main parameters and data sources used for THC Production analysis

Parameter	Source(s)
1. Dry flower and number of plants harvested in 2017	BioTrackTHC seed-to-sale traceability data
2. Dry flower and number of plants harvested in 2023	Simulation based
2a. Number of active producers	Department of Revenue (DOR) and Liquor and Cannabis Board (LCB) data on production licenses
2b. Listed canopy per producer	LCB data on canopy
2c. Yield per square foot of canopy	Literature review
2d. Space per plant	LCB draft plant report

Note on Data Sources

The original goal was to estimate production in terms of weight of flower and weight of delta-9-tetrahydrocannabinol (THC) for 2017, 2019, 2021, and 2023. Estimates for 2017 were based on previous RAND research (Kilmer et al., 2019) which used BioTrackTHC data. In 2018, LCB switched their cannabis tracking system from BioTrackTHC to Leaf and then, in 2021, from Leaf to CCRS. Due to significant data limitations with the Leaf and CCRS datasets, production for 2023 was calculated using alternative data sources to ensure accuracy and completeness. The RAND team was unable to estimate production for 2019 and 2021 due to data limitations.

Methods

For 2017, production estimates were generated using BioTrackTHC data. For more information, please refer to previous RAND research (Kilmer et al., 2019).

Because there was a tremendous amount of uncertainty surrounding the parameters for 2023 cannabis production, a Monte Carlo simulation framework was employed to estimate the total weight of dry flower produced, and total number of plants harvested. The following parameters were used for the simulations:

- **List of active production licenses and listed canopy per license**. License information provided by LCB was used to identify licenses that were likely active producers in 2023 (from wholesale tax revenue data from the Department of Revenue, CCRS reporting data provided by LCB, and license closure dates provided by LCB). License information included license tier, listed canopy amount, and license cultivation type (indoor, outdoor, or both). The RAND team filtered licenses based on activity status, production license (i.e. removed retail licenses), and if the license closed during 2023, in which case the license was assigned a partial year of activity based on the closure date.

1. **Percent of canopy used**, which the RAND team imputed to be a uniform distribution from 40% to 80% for indoor cultivation types, a uniform distribution from 40% to 80% for 90% of outdoor cultivation types, and a normal distribution with mean 110% and 10% standard deviation for 10% of outdoor cultivation types. This was based on conversations with LCB which indicated that many licensees may not use their entire canopy for production but some outdoor licensees may overproduce.
2. **Space per plant**, which were estimated to be a uniform distribution from 2 sqft to 4 sqft for indoor cultivation types, and 2 sqft to 5 sqft for outdoor cultivation types. This was based on a recent LCB draft memo, along with the assumption that more space per plant was used for outdoor production.
3. **Number of harvests per year**, which were estimated for indoor cultivation types to be 2 for 5% , 3 for 10%, 4 for 40%, 5 for 30%, and 6 for 15%. For outdoor cultivation types, the RAND team estimated this to be 1 for 40%, 2 for 40%, and 3 for the remaining 30%. This was based on the existing literature combined with input from LCB, who indicated that observed harvests are more frequent than what past literature suggested.
4. **Yield per harvest**, which were estimated to be a triangle distribution between 30 and 50 grams per square foot, with a peak at 40 grams per square foot for both indoor and outdoor cultivation types. This was based on previous literature.

Findings

From BioTrackTHC, the production estimates for 2017 were as follows:

- 2.5 million cannabis plants
- 266 MT (0.6 million pounds) of dried harvested flower
- 55 MT (0.1 million pounds) of THC produced as dry flower

After running 1,000 simulations using the specified framework, production estimates for 2023 were as follows:

- 6.2 million cannabis plants were produced[1]
- 770 MT (1.7 million pounds) of dried harvested flower[2]

The RAND team was unable to estimate THC produced in 2023, as the available data did not include "other plant material", which is used in producing concentrates. A speculative estimate

[1] 10th percentile: 5.1 million; 90th percentile: 7.4 million

[2] 10th percentile: 620 MT (1.4 million pounds); 90th percentile: 920 MT (2.0 million pounds)

of THC content produced as dry flower was computed, which was 165 MT (0.4 million pounds)[3]. This was produced by multiplying the weight of dry flower produced by the assumed average THC content. Following the pattern seen in THC content in 2017, assumed THC content for dry flower in 2023 was taken to be one percentage point lower than the average THC content of retail flower.

The plant values generated by the RAND team (6.2 million; 5.1 million-7.4 million) are in the same ballpark as recent LCB estimates (5.5 million plants) despite using a different methodology. RAND's dried flower estimate (1.7 million; 1.4 million-2.0 million) was consistent with the estimate produced by Whitney Economics (1.6 – 1.8 million pounds).

Limitations/Caveats of Utilized Datasets

The wide range in 2023 estimates was due to the uncertainty in simulation parameters. For Washington cannabis producers in 2023, the RAND team had no data on the amount of listed canopy used in production, no data on the space needed per plant, and no data on the number of harvests each year. Additional uncertainty comes from 1) licenses with cultivation type listed as "both", which accounts for 26% of active licenses in 2023, and 2) no way to identify the use of greenhouses or how greenhouses would be classified in terms of cultivation type. For the simulations, a cultivation type of "both" was assigned as outdoor. If "both" was instead assigned as indoor, estimated production increases by over 30%, highlighting the substantial uncertainty in the estimates stemming from the lack of clarity on key aspects of production.

Limitations of Original Data Sources

While Leaf was designed as a traceability system, it was never fully implemented. CCRS was not designed as a traceability system; as such, it was impossible to use the data to determine cannabis or THC produced. Leaf only tracked data as a "snapshot in time"; once a producer sold out of a specific product, the inventory was listed as zero, with no way of knowing what the initial inventory value was. Additionally, due to a lack of linking variables in Leaf, there was no way of linking THC percentages with cannabis produced. CCRS had similar problems, with no linkage between production identifiers and THC testing. CCRS had high rates of de facto missingness: licensees were able to report a weight of 0 for flower lots, which occurred 39.3% of the time. These issues precluded both Leaf and CCRS from being reliable sources of data for production estimate.

[3] 10th percentile: 133 MT, (0.3 million pounds); 90th percentile: 197 MT (0.4 million pounds)

1.B: Estimating Sales

Data Sources

The main data sources used for THC sales analysis are listed in Table 1.B.1.

Table 1.B.1 Main parameters and data sources used for THC Sales analysis

Parameter	Source(s)
1. Sales 2020 - 2023	Third-party (Headset.io) data purchased by JLARC for RAND use. Covers over 80% of retail sales and imputes to be representative of total legal sales in Washington. Includes state-level sales in dollars and number of items. Includes THC for some product types.
2. Sales 2016 - 2023	Administrative data from LCB's tax unit and license information provided by LCB. Tax data included sales in dollars by license. License information data included geographic location of license.
3. Sales 2016 - 2017	BioTrackTHC data and analysis done by Kilmer et al. (2019). Included sales in dollars and THC. Included splits by product type.
4. 2023 THC content	Websites such as Leafly. Researcher imputation.

Note on Data Sources

Washington State Liquor and Cannabis Bureau has used 3 different systems to collect their cannabis data since legalization, with manual contingency reporting between formal systems. BioTrackTHC was used from early 2014 through the end of October 2017, when LCB switched to Leaf. Leaf was used from February 2018 to December 2021, at which point LCB began to use their proprietarily developed system called the Cannabis Central Reporting System (CCRS). CCRS is still in use today. Due to significant data limitations with the Leaf and CCRS datasets, sales for 2023 were calculated using Headset.io, which provided real-time data and analytics for the cannabis industry in Washington state using point-of-sale systems, dispensary partners, and retail sales data, to ensure accuracy and completeness.[4]

[4] Starting in June of 2024, House Bill 1453 went into effect and medical cannabis sales were henceforth exempt from excise taxation. This implies that those sales would no longer be included in either the third-party Headset.io data or the LCB tax unit data. As medical cannabis sales were taxed up though 2023, those sales are included in these analyses.

Methods

The methodologies for estimating the total (pre-tax) dollar sales, sales by product type, sales by geography, and total amount of THC sold by licensed retailers are described below:

1. **Total pre-tax sales** by available year were compared across the three data sets: BioTrackTHC 2016-2017, LCB tax data 2016 – 2023, and Headset 2020 – 2023.
2. **Sales by product type** used retail product types from 2016-2017 from BioTrackTHC data and retail product types from 2023 from Headset. To compare over time, the products were grouped into comparable bins: flower, extracts, edibles, and beverages.
3. **Sales by geography** were calculated by linking licenses from the tax data to the license information data, which includes county information for the license.
4. **THC sold** was calculated as THC sold by product type, aggregated over the different product types. For 2016-2017, BioTrackTHC data were used, which link tested products to retail products. BioTrackTHC data for the THC content of edibles were not available, so THC content was instead imputed based on valid THC observations from product labels. THC sold in 2023 required several approaches:
    a. For edibles, beverages, topicals, tinctures/ sublinguals, and capsules, the Headset data contained THC by package size (e.g. edible items with 100mg THC) and number of units sold by package size. These were used to calculate total THC for each product, with some imputation for package sizes listed as a range or marked "Other."
    b. For flower, vape pens/carts, pre-rolls, and concentrates, there were multiple steps to compute total THC sold by product type:
        i. The top 50 products sold were pulled from the Headset data and were split by package size (weight in grams) for all but pre-rolls, which were split by infused/non-infused.
        ii. Web sources were used to impute the THC content for the top 50 products sold.
        iii. The average THC by package size (and infused/non-infused pre-rolls) was computed for the top 50 products sold.

- That average was used as the average THC by product size for all products sold in that size category.[5,6]
        iv. Average THC by product size multiplied by total sales in grams for that product size was aggregated over all product sizes to estimate total THC sold.

Findings

Total pre-tax sales in dollars for overlapping years from the different data sources were consistent within 4 percent and most often within less than 1 percent. When using the different data sources, for example splits by geography from tax data and splits by product type from

[5] The top 50 products sold account for between 7% and 19% of all products sold, depending on product type and whether one considers sales in dollars of number of items sold.

[6] For vape pens/carts, roughly a third of the top 50 products sold were low potency (THC concentration of 50% or less). The total share of low-potency products was adjusted down to 5% based on recent data from California.

third-party vendor data, no adjustments were made to any source. While the market share of flower has been declining over time, in 2023, flower still had the largest market share in both sales in dollars and THC sold. Pre-rolls had the largest market share in sales by number of items sold. Sales by geography were stable from 2019 – 2023, with western counties accounting for just over three-quarters of total dollar sales and the five most populous counties (King, Pierce, Snohomish, Spokane, and Clark) accounting for approximately two-thirds of total dollar sales.

From 2017 to 2023, THC sold roughly doubled from 31MT to 63 MT. From 2017 to 2023, the amount of THC sold in flower products (grouped) increased by approximately 70 percent while the amount of THC sold as extracts or edibles tripled. There was no evidence that average THC concentration of flower has changed in that period, with an average THC concentration around 22%. The potency of extracts for inhalation (which includes vape pens/carts and concentrates) increased since 2017, with an average THC concentration of almost 85% in 2023 compared to roughly 70% in 2017.

Limitations/Caveats of Utilized Datasets

Comparing products across time required grouping into comparable product types ("flower products" as flower and pre-rolls in 2023, and usable marijuana, marijuana mix infused and marijuana mix package in 2016/2017) as well as limiting to product types with THC information in 2017, which excluded topicals, tinctures, capsules, transdermal patches, and suppositories. For 2017, data were missing for November and December and had to be imputed. (November and December 2017 figures were projected based on the percentage increase in January – October sales from 2016 to 2017, applied to November-December sales for 2016.) For 2023, the third-party data comprised over 80% of retail sales. The remaining sales were imputed so that the data is representative of the total 2023 market.

The RAND team's THC estimates had uncertainty, especially for flower, vape pens/carts, pre-rolls, and concentrates in 2023. For 2016 and 2017, THC for edibles had to be imputed based on label information. While the exact percentage varied by product type, the top 50 products sold accounted for less than 20% of all products sold for any given type in 2023. It was assumed that the THC distribution of the top 50 products sold was representative of the total distribution of all products sold. If instead, the top 50 products were on average more potent, the estimates presented here would be over-estimates.

Limitations of Original Data Sources

Leaf sales data were in terms of number of items, with no information about weight; therefore, Leaf data could not inform the total weight of cannabis products sold or the amount of THC sold. CCRS data had no linking between lab results and sales, making it impossible to use CCRS to determine amount of THC sold. Additionally, it was discovered through conversations with LCB that some of the sales data from August – December 2023 was "booted off the

system", and, as of this report, there was no confirmation of whether the data was recovered in full.

1.C: Estimating THC Consumption

Data Sources

The main data sources used for this analysis are listed in Table 1.C.1.

Table 1.C.1 Main parameters and data sources used for this analysis

Parameter	Source(s)
1. Number of people residing in Washington who used cannabis in the past month	State-level estimates from the National Survey on Drug Use and Health; Washington State Behavioral Risk Factor Surveillance System; Washington Office of Financial Management (for state population figures)
2. Distribution of use days for past month users	Washington State Behavioral Risk Factor Surveillance System; International Cannabis Policy Study; Caulkins & Kilmer (2013)
3. THC consumed during typical use day for daily/near daily (DND) users	Kilmer et al. (2019); Budney et al (2024); Borodovsky et al. (2024)
4. Percent THC consumed during a typical use day for Occasional and Frequent users, as a function of DND THC consumption	Previous literature; International Cannabis Policy Study

Methods

The methodology for estimating the total amount of THC consumed[7] follows seven major steps:

1. Determined the number of past-month cannabis users in WA for 2023
2. Placed these individuals into three categories
    a. Daily/near daily (DND): Used cannabis 20+ days in the past month
    b. Frequent: Used cannabis 6-19 days in the past month
    c. Occasional: Used cannabis 1-5 days in the past month
3. Calculated the total number of past month use days for these three groups
4. Multiplied the DND past month use days by the amount of THC consumed during a typical use day by DND users
5. Assumed Frequent users used, on average, 50% of the amount of THC consumed by DND on a typical use day. For Occasional users the figure was 40%. Conducted Step 4 for Frequent and Occasional users
6. Summed past month THC consumption across the three groups

[7] This report uses the term "consumption" to capture the THC a person uses. This is not the same as the amount of THC absorbed into the bloodstream. Absorption can depend on several factors, especially the method of consumption that gets the THC into the body.

7. Multiple this figure by 12 to generate annual estimates (as justified in Caulkins & Kilmer, 2013).

Of course, there was uncertainty surrounding many of these figures. Thus, the RAND team utilized a simulation framework which accounts for the uncertainty. Each trial of the simulation pulled a value from the distribution of past-month users[8] and THC consumption during a typical day for DND users,[9] and then multiplied these values by the distribution of use DND days. Similar calculations were made for Frequent and Occasional; however, their daily consumption rates were a function of the value drawn for DND users. Adding these three figures up and multiplying by 12 generated annual estimates of THC consumption. We then ran the simulation 9,999 more times.

Findings

After running 10,000 simulation trials, the RAND team found that individuals in Washington consumed an average of 87 MT of THC in 2023 (median 85 MT), with the 10th and 90th percentile values being 66 and 113 MT, respectively. This uncertainty was largely driven by amount of THC consumed per use day by DND users. Additional sensitivity analyses focused on 1) the possibility NSDUH underestimates consumption and 2) testing other key assumptions suggest it was reasonable to assert that the total amount of THC consumed by individuals living in Washington in 2023 was *on the order* of 90 MT.

Based on our estimates of THC purchased in Washington's licensed stores and assumptions about share purchased by those living outside of Washington (Kilmer et al., 2019, p. 34), it was reasonable to assert the share of THC consumed by those residing in Washington coming from Washington's licensed retailers likely ranged below 70% and higher than 60% in 2023. However, given the uncertainty surrounding the denominator (the 10th and 90th percentile values being 66 and 113 MT, respectively) this actual figure could be lower or higher.

Limitations/Caveats of Utilized Datasets

This wide range was largely driven by the uncertainty surrounding amount of THC consumed per use day by the daily and near daily users who account for most of the consumption. The proliferation of non-flower cannabis products made it harder to generate these daily THC consumption estimates.

[8] Triangle distribution. Low: 1,011,000; Middle: 1,402,629; High: 1,582,112

[9] Triangle distribution. Low: 260mg; Middle: 325mg; High: 600mg