Energy Benchmarking Report

Phase 3 Report - Revised January 3, 2022

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Introduction

As the regulated cannabis cultivation expands, its high resource use continues to gain attention. State-level policy makers are looking to regulate limits on energy use, often without proper input from cultivators while customers demand more information about the source of their products. By voluntarily cataloguing and disclosing energy use and carbon footprint, Glass House gains the opportunity to weigh-in with regulators and policy makers about what is and is not reasonable to require from cultivators and win dedicated customers with strong values.

In order to set realistic goals or make effective investments Glass House needs to catalog and understand the impact of their current facilities. Common sustainability goals require an established baseline and assessment process. Furthermore, a comprehensive baseline of energy use prepares an organization to determine where and how they can most effectively invest in energy efficiency to achieve the greatest reductions while maximizing the company's bottom line.

Summary

Glass House Group's (GH) cannabis greenhouses outperform industry competitors by 10-90% in nearly every efficiency measure evaluated.

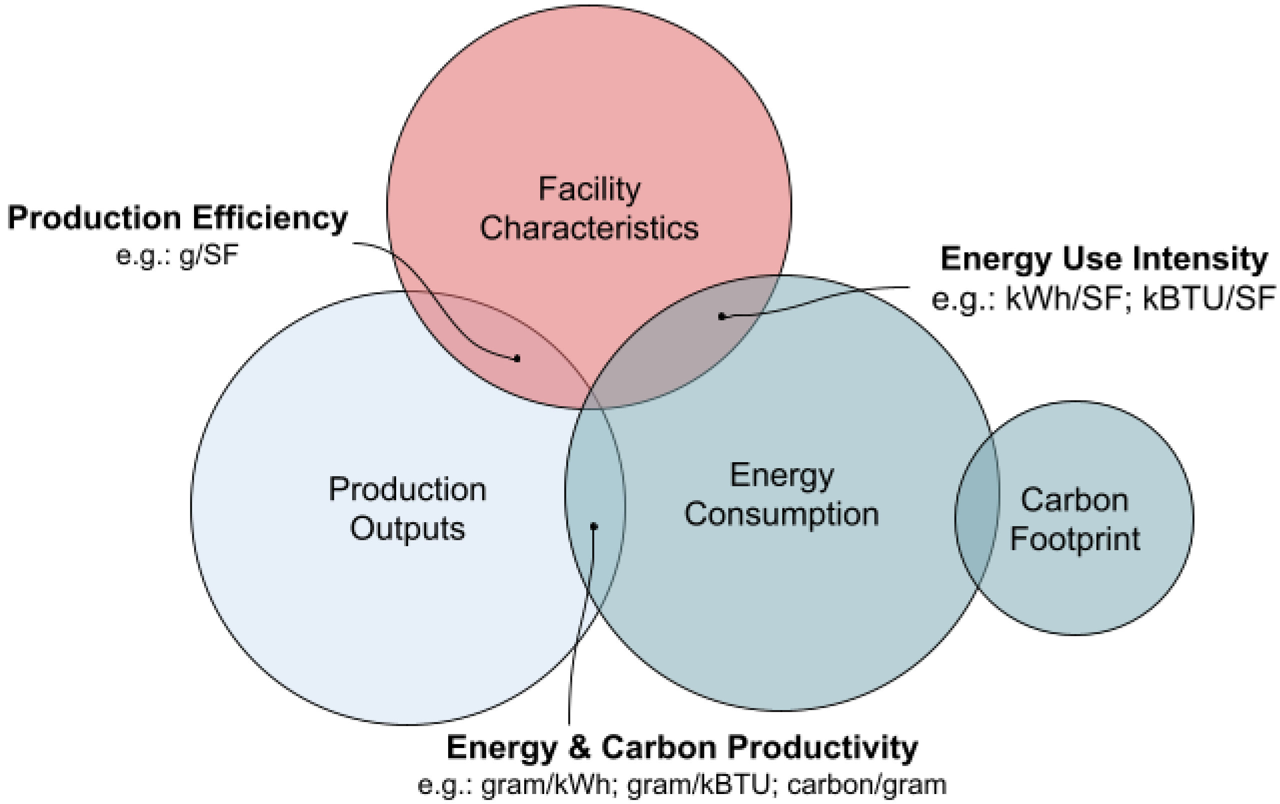
Compared to the best available data for industry averages, Glass House Group's facilities report:

- **Energy Productivity, Electric (g/kWh):** GH yields approximately 7 *times* more per unit of electricity used than standard greenhouses.
- **Facility Energy Intensity (kWh/SF) :** GH uses approximately 88%% less electricity per SF than typical greenhouses and 93% less than indoor.
- **Production Efficiency (grams/SF):** GH produces **180% more yield per SF** than industry standard greenhouses.
- **Carbon Productivity (kgC02/kg flower):** GH produces **67 more cannabis per unit of carbon** than other greenhouses, and **96%** more than indoor facilities.
- Glass House Greenhouses appear to use **68% less carbon per gram of flower than other greenhouses, and 96% less than indoor operations.**

Summary: Efficiency Metrics	**Glass House Avg.**	**Industry Average, Greenhouse**	**Industry Average, CA Indoor**	**Notes**
Energy Productivity, Electric (g/kWh)	8.6	1.1	**0.8**	compared to Cannabis Power Score (CPS) data
Energy Productivity, Electric + Gas (g/kBTU)	0.5	unknown	***unknown***	*unknown; CPS benchmark does not include gas*
Electric Energy Use Intensity (kWh/SF)	15	134	**262**	per SF of flowering canopy; compared to CPS benchmark
Energy Use Intensity (kBTU/SF)	256	314	**709**	compared to CPS; comparison excludes gas energy
Production Efficiency (grams/SF)	134	48	**174**	Yield per SF of flowering canopy
Carbon Productivity (kgC02/kg flower)	100	314	**2,643**	Compared to Summers report, extrapolated to greenhouse; isolating for facility only carbon consumption

Framework - Inputs and Efficiency

This analysis in this report is based on three primary input categories: facility characteristics, production yields, and energy consumption. The carbon impacts for Glass House included in this analysis are limited to and based directly on on-site energy (gas + electric) consumption. The intersection of the three primary inputs and how they are used to calculate metrics are displayed below.



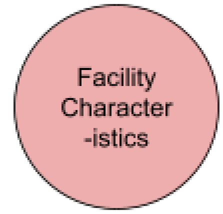
Each intersection presents a different perspective on productivity and efficiency. Different metrics are used by different audiences and for different purposes.

Inputs - Glass House Snapshot

The following inputs, summarized in the table below are used for the evaluation metrics. Each will be further detailed. All input variables are collected at the site level and are then added together and displayed as the "GH Total" for Glass House Group Total. Company level metrics are then calculated based off of these total values, eliminating the need to weight any numbers by an outside factor. The GH Total and GH Average values are displayed on all of the tables and charts below

Input Summary		***GH Total***
Total Area	*square feet*	502,003
Flowering Canopy	*square feet*	296,000
Yield, Dry Flower	*grams*	39,519,792
Electricity	*kWh*	80,076,621
Gas	*Therms*	603,424
Carbon	*tons C02e*	3,969

Facility Characteristics



The basic facility inputs that will help benchmark Glass House's energy consumption are the total facility square footage and the flowering square footage. The total facility square footage will be used in the Energy Use Intensity comparisons, allowing us to compare gross energy use (both electricity, gas, and combined kBTU) to other industries; this is a common approach to sizing up energy use in the built environment within the energy and utility sector.

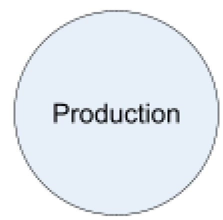
Flowering square footage is a metric that is unique to the cannabis industry. However, it is an easy number to track as licensing is often tied to it, at least as a maximum threshold. Most energy metrics regarding facility productivity in the cannabis industry are based on the flowering square footage input. The assumptions for the gross square footage and active flowering canopy are based on primary input from Glass House Director of Engineering, Philip Van Spronsen. The numbers are are below:

		Total
Total Area, SF	*input*	502,003
Flowering Canopy, SF	*input*	296,000

Time Frame

The energy data used to inform this report represents activity from May 2020 through April of 2021.

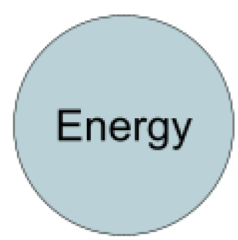
Production Yields



The key production variable that will be used to contextualize a facilities' production to its size and resource use are the grams of dried cannabis flower produced per year. The annual production yields from Glass House Group facilities are approximate, and based on a bottom-up analysis based on input from Philip Van Spronsen of Glass House. To arrive at dried cannabis product yield we began with pounds of wet weight harvested per week and applied assumptions based on internal historical data regarding wet weight loss and final yields. Final dried cannabis weight includes flower, smalls and trim. The table below summarizes the input and final output values for dried cannabis flower for the two facilities combined.

lbs of dried cannabis product per year	*calculated*	87,000

Energy Consumption



On-site energy consumption is the driving input behind energy and carbon benchmarking for this analysis. The scope of this study is limited to on-site energy consumption from gas and electricity - and does not address the embedded energy in other inputs or transportation or other energy costs associated with delivering cannabis product to market. It is worth noting that many of the other cannabis industry benchmarks and surveys that are referenced for comparison purposes only address electric energy consumption, limiting the ability to adequately compare facilities. Glass House is reporting comprehensive data regarding both electricity and gas consumptions for its cultivation facilities.

Energy consumption for Glass House is derived from actual monthly bills from Southern California Edison (based on 15 minute consumption data) and from Southern California Gas. Note that one of the facilities–Padaro–has only been fully operational since December of 2020, so the 12 month data was extrapolated based on best estimates of the facility being operational during the sample period.

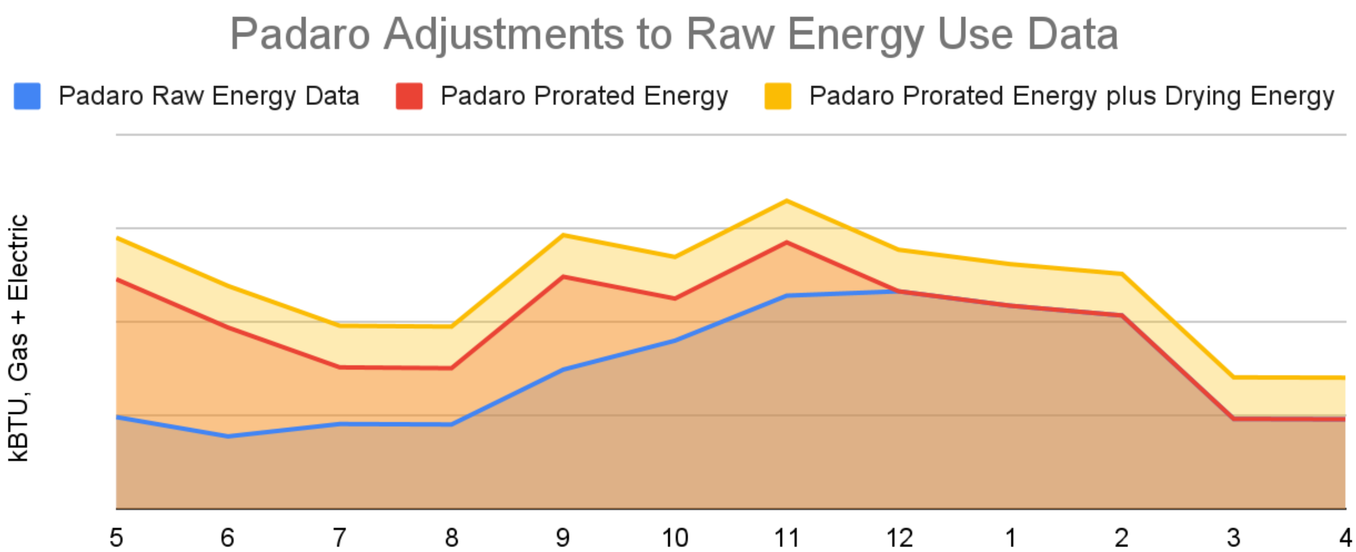
Adjustments to Energy Inputs.

We applied two adjustments to the raw energy use data - both of which added a total of 63% energy use to the observed energy bills for Padaro. The first was prorating the gas and energy use by a factor of "percent operational" according to input from facility lead & Director of Engineering, Philip van Spronsen. According to Philip, Padaro was brought online in large "steps". Thus, the input assumptions are that the facility was 30% operational in January of 2020, 40% in April, 60% in July, 80% in October and 100% in January 2021. We wanted the energy calculations to reflect the facility when running at full capacity.

The second adjustment made to Padaro was to include the energy use associated with off-site drying of wet cannabis products, which is a common industry practice in the cannabis industry. Thus, to fairly represent the energy use associated with Padaro and create an apples-to-apples comparison internally and to the industry at large, we added in the calculated energy use associated with dry cannabis onsite to the raw Padaro energy use data.

Empirical data about energy use associated with drying cannabis remains elusive industry-wide, however we were grateful to find a forecast value of 0.09 kWh per gram of dry cannabis from Dr. Evan Mills' 2011 analysis. Based on the dehumidification equipment used at the time of the 2011 Mills' report the 0.09 kWh per gram value is likely overstated by 100% or more. In other words, even though a modern, commercial scale dehumidification facility will dry cannabis far more efficiently than a 2011 era residential scale dehumidifier, we used the latter value to remain conservative in our efficiency claims. This energy expense of 0.09 kWh/g was added to the Padaro energy use input, based on grams of dry cannabis product produced by month.

The effects of these two adjustments to the raw Padaro energy data is an increase of 63% from actual measured energy use. This includes 33% from prorating the energy use during the facility buildout, and 23% more (compounded on top of the 33%) for associated drying energy use.



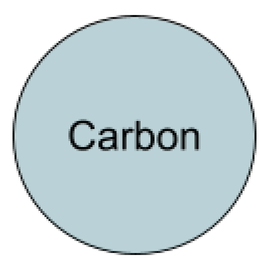
		Total
Electric Annual kWh	*input*	4,559,092
Gas, Annual Therms	*input*	603,424

In order to evaluate electricity and gas consumption on equal footing we convert electric and gas energy data into kBTU, or "thousands of BTUs". 1 kWh = 3.412 kBTU; 1 therm of gas equals 100 kBTU. Thus, the summary of energy consumption for Glass House's two facilities is as follows:

		Total
kBTU, Electric	*converted*	15,555,623
kBTU, Gas	*converted*	60,342,358
kBTU, Electric + Gas	*sum*	75,897,981

Because Glass House's greenhouses employ very little supplemental lighting, 80-95% of the onsite energy consumption is from natural gas. Gas consumption is driven by demand for C02, heating and humidity regulation.

Carbon Conversion



Energy consumption can be easily converted into carbon footprint by applying standard conversion factors from the source data. The source data for carbon is kWh of energy from Southern California Edison, and therms of gas from Southern California Gas. We use a carbon conversion factor from Southern California Edison (of 0.169 MTons of C02e/MWh[1]), and EPA values (of 0.0053 tons C02e/therm[2]) for natural gas.

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[1] https://www.edison.com/content/dam/eix/documents/sustainability/eix-esg-pilot-quantitative-section-sce.pdf
[2] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

Carbon Footprint

The onsite energy carbon footprint of Glass House's facilities is 3,969 metric tons of C02 annually. Most of this carbon footprint is associated with the use of on-site natural gas for greenhouse heating.

	Total
Electric - Mtons C02e	770
Gas - Mtons C02e	3,198
Total Mtons C02e	**3,969**

For scale, this equates to the equivalent carbon footprint of 863 US vehicle-years or 478 US household-years.

	GH Total
Vehicle-years	863
US Households	478

Efficiency Metrics - Energy and Carbon Metrics

Production Efficiency

Production efficiency tells us how much yield a facility produces per SF, regardless of the resources involved. For this metric we use grams of dry cannabis flower and square feet of flowering canopy.

Production Efficiency	***GH Average***
G/SF	134

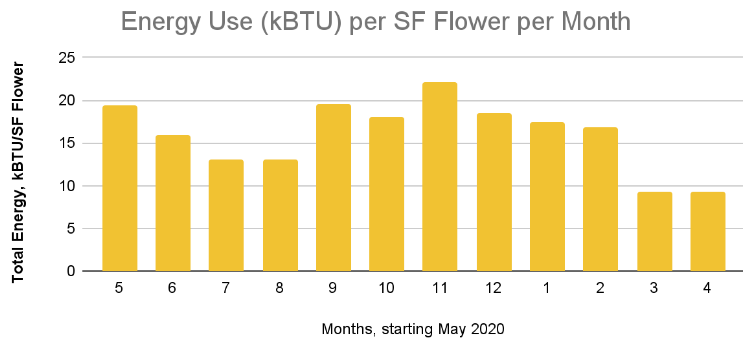
Energy Use Intensity

Energy Use Intensity (EUI) is a common metric in the building science and energy efficiency industry. EUI contextualizes energy use to the building square footage - regardless of output. EUI values within the cannabis focus on square feet of flowering canopy only, as flowering canopy is the driver for revenue. Traditional building EUIs often compare EUIs across sectors using total building square footage.

On an annual basis Glass House facilities use approximately 207 kBTU per SF of flowering canopy, and about 150 kBTU/SF for the entire facility inclusive of non-flowering areas. Per square foot of flower canopy, Glass House uses about 13 kWh/Sf.

Energy Use Intensity	***GH Average***
Annual kBTU/SF Flower	256
Annual kBTU/SF Total Facility	151
Annual kWh/SF Flower	15
Annual kWh/SF Total Facility	9

The energy usage per SF at Glass House's facilities does demonstrate a heating signature, where the facilities use more energy in the winter months than in the summer. Indoor operations, by comparison, generally do not demonstrate a typical heating signature as their energy profile is typically dominated by higher energy use for horticulture lighting and significant air conditioning and very little heating even in the winter.



Energy & Carbon Productivity

Energy productivity metrics tell us how much energy (and carbon) is required to produce a gram of dried cannabis. The inverse metric is also common: how many grams of dried cannabis are yielded per unit of energy (kWh or kBTU).

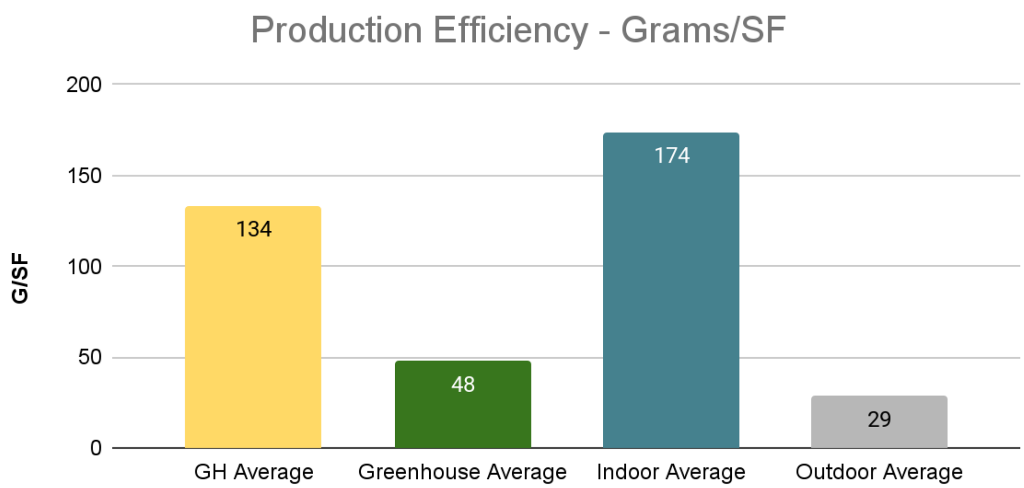
Because so many conversations in the indoor cannabis industry articulate energy use in simple electric terms (kWh/lb), we include both electric on its own as well as electric and gas together. For carbon, the leading metric (popularized by Evan Mills and later by the Summers 2021 report) is "kilograms of carbon per kg of dried flower", or kG C02e/kg.

Energy & Carbon Productivity	***GH Average***
kWh/lb	52
kWh/g	0.115
kBTU/Gram	2
Gram/kWh	9
Grams/kBTU	0.52
kG C02e/kG	100

Industry Comparison - Energy and Carbon Metrics

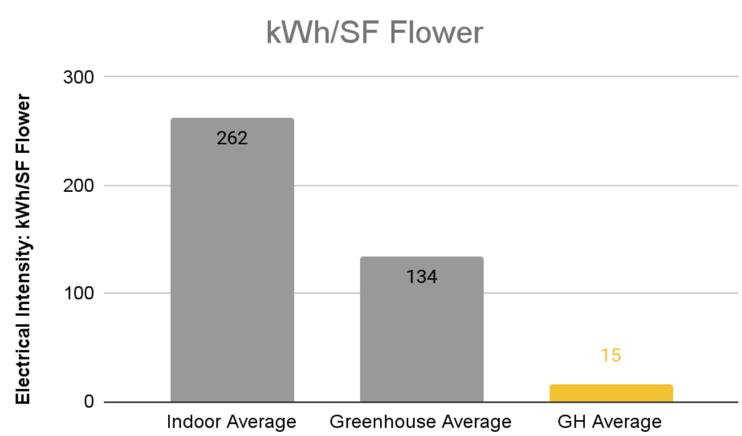
Production Efficiency

Maximizing yield per SF is a motivating factor for any commercial cultivator. Industry comparison statistics shown here are from the Resource Innovation Institute's Cannabis Power Score data, which is based on self-reported cultivator data. Outdoor is uniquely shown on this chart as a point of interest. Glass House facilities' average yield is 179% higher per SF than a typical industry average greenhouse and 360% higher than outdoor, but about 23% lower than a typical indoor facility.



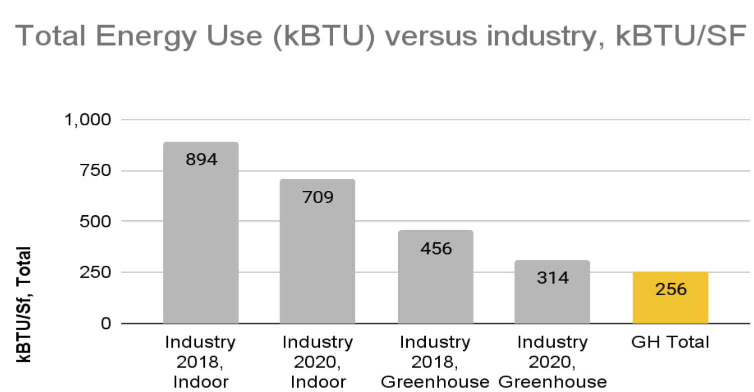
Energy Use Intensity

Compared to industry standard values, Glass House uses 12% of the electric energy use per SF as an industry average greenhouses, and 6% of indoor facilities. In other words, while **Glass House achieves slightly less (23%) yield per square foot compared to an indoor facility, it accomplishes this with 94% less electricity.**



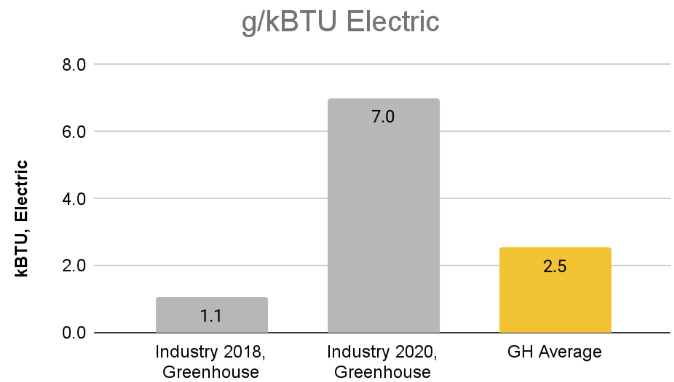
Converting electricity into kBTU Glass House still consumes far less than industry reported values for greenhouse and indoor.

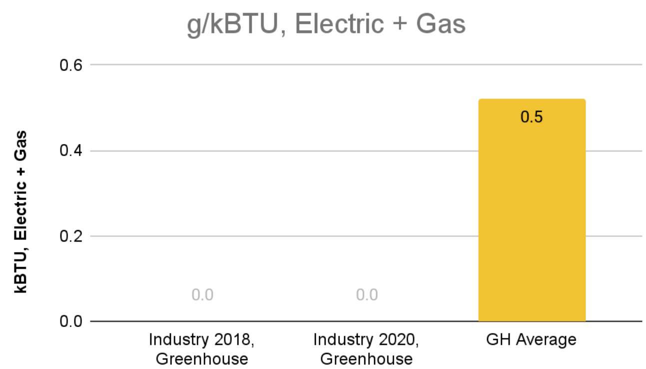
Note that the comparison data for industry averages (from the Cannabis Power Score Report) does not include gas usage (it only includes electric) so the overall energy use (kBTU) is significantly underreported, especially for greenhouses where gas makes up a larger proportion of facility energy use.



Energy Productivity

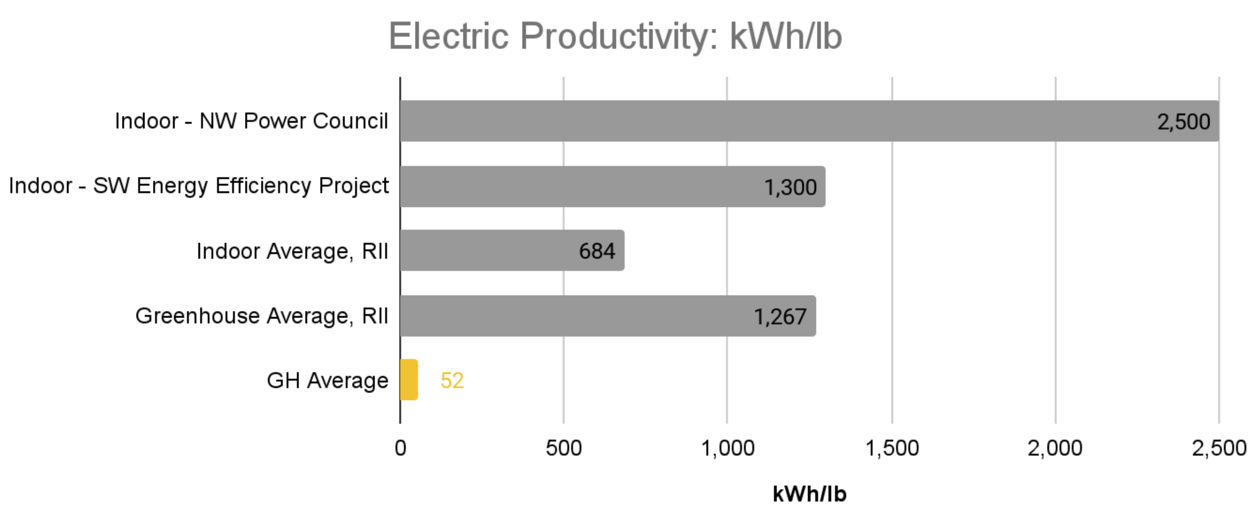
Many metrics for energy productivity were provided above, but grams of yield per unit of energy rises to the top for usefulness. Note that due to a limited data set for the industry at large we can only effectively compare to electric energy; gas energy use is not available. In terms of grams of yield per kBTU *of electricity*, Glass House yields 1.5-3x the industry reported average or more.





Electric energy (kWh) per pound of flower is another metric that is often thrown around in the media, without much data to support claims. Energy professionals (non-cannabis industry experts) have published speculated values indicating that between 1,300-3,000 kWh of electricity is used to cultivate 1 dried pound of flower - or approximately $130-300 at $0.10/kWh electricity cost. The value for Glass House Group is less than 100 kWh/lb - or 90+% less than the published values..

The chart below summarizes published estimates of kWh per lb of dried flower. The first two bars are energy efficiency policy groups that *projected* energy use on a per square foot basis to be between 2000-3000 kWh/lb (NW Power and Conservation Council) and 1,300 kWh/SF (Southwest Energy Efficiency Project). The next two bars appear suspect because the self-reported energy use for greenhouses is higher than the self reported energy use per pound indoor. Because this data is from the Resource Innovation Institute's Cannabis Power Score we can not validate results. However they are shown for comparison purposes.



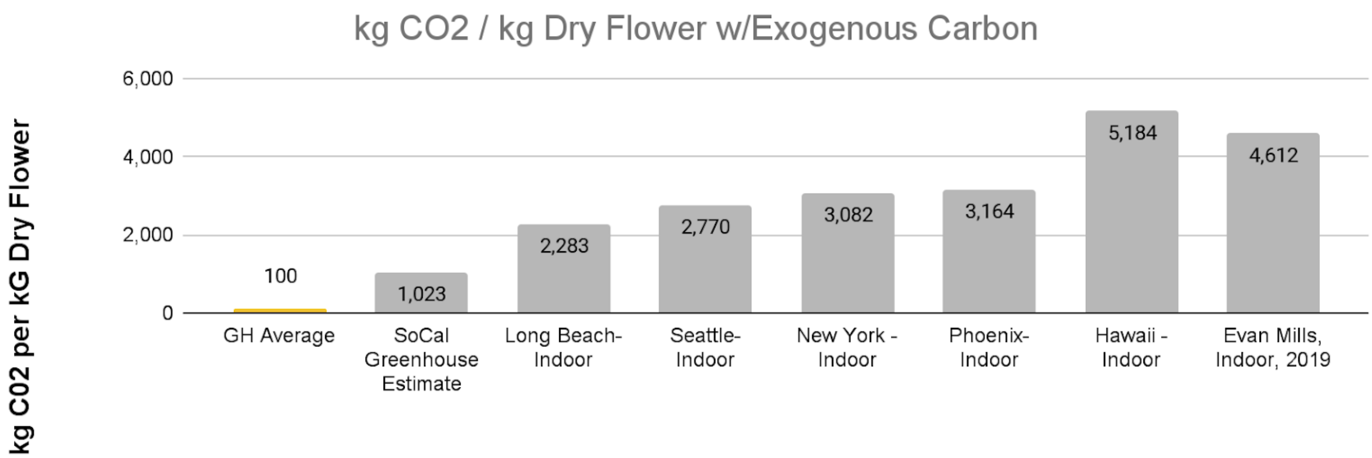
Carbon Productivity

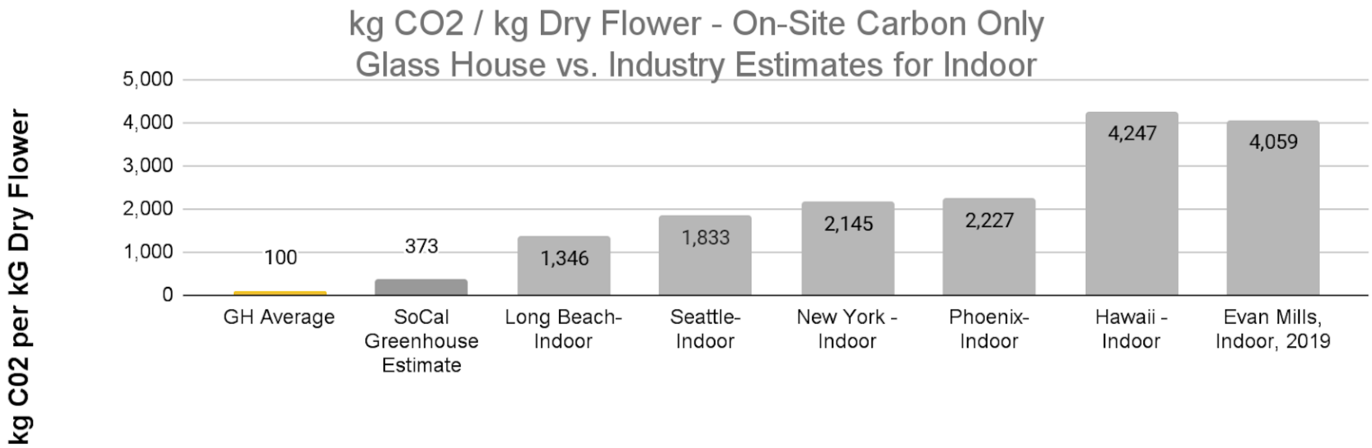
Carbon productivity, or the carbon resource per unit of cannabis, has been in the news lately with alarming headlines. The Summers 2021 report is built upon the framework set by Evan Mills in 2011. The guiding metric used in both of these reports show carbon in terms of kilograms of C02 per kG of dry flower.

Both Summers ‘21 and Mills include lifecycle carbon costs in their estimates of carbon use including factors such as transportation, the bottling and shipping of C02, nutrients and grow media, etc. The Summers report also places aggressive (possibly unfounded) emphasis on the energy use from HVAC air movement, assuming over 30 air changes per hour *of outside air* in a cannabis facility.

Our analysis attempts to contextualize these reports in two steps. First, the analysis pro-rates estimated carbon use from an indoor grow within Southern California to a local greenhouse by limiting the carbon assumptions to only those variables that apply to greenhouses. And second, this analysis by isolating the energy and carbon resources used at the site level rather than at a global or “life-cycle” value.

Isolating carbon uses from variables not associated with on-site energy use (e.g.: removing embedded carbon cost of bottling and transporting C02 (which most greenhouses do not do anyways), carbon transportation to market, and massive outside-to-inside air changes per hour assumptions), the Glass House carbon footprint (per kg dried flower) looks as follows when compared to the Summers and Mills projections for indoor cannabis.




kg CO2 / kg Dry Flower - On-Site Carbon Only
Glass House vs. Industry Estimates for Indoor
kg C02 per kG Dry Flower
5,000
4,000
3,000
2,000
1,000
0
100
373
1,346
1,833
2,145
2,227
4,247
4,059
GH Average
SoCal Greenhouse Estimate
Long Beach-Indoor
Seattle-Indoor
New York - Indoor
Phoenix-Indoor
Hawaii - Indoor
Evan Mills, Indoor, 2019

Recommendations

1. Consider carbon neutrality. If Glass House wanted to purchase carbon offsets to help mitigate its carbon footprint, the cost would be $29,000-$119,000 annually, based on an offset cost of $10-$40/ton.[3] This equates to $0.41-$2.72 per lb of final dry product.

2. Expand resources use inputs to include:
    a. Water
    b. Waste
        i. Water runoff
        ii. Solid waste
        iii. Organic waste

    While not as mainstream a concern as energy use in the cannabis industry, many in the sustainability community are asking questions (of themselves and of the industry) about water use and waste streams associated with commercial cannabis cultivation. The handling of organic waste (e.g.: treating excess biomass as a biohazard versus a compostable organic product) is evolving as regulators learn more about the plant and the industry. Colorado now allows commercial composting of waste product and similar regulations will likely spread across the country.

    We are currently unaware of any regulations to curb water use in the cannabis industry, however it is not unfathomable that such regulations will develop. New York, during preliminary rulemaking, suggested a rule that would require all water and wastewater be measured at the room level, requires water recapture and reuse, and requires that no more than 20% “waste to drain” be allowed. While these all sound well-intended, it is unclear if the industry hardware and SOPs or other chemical constraints (e.g. concentration of nutrients) have been considered with industry input.

3. Continue to validate input assumptions for cultivation yields, especially the wet-to-dry weight input. From conversations with Philip Van Spronsen, 7-10% is typical dry weight (per unit of wet weight); we conservatively used 7% for this model. Double check modeled yields against actual dried flower yields.

4. Disaggregate energy use by end use.Increased understanding of how energy is being used for different functions (lighting, heating, C02 generation, processing, admin & offices, etc.) will inform energy management discussions and opportunities for improvement.

5. Begin to sub-meter energy and gas uses wherever possible.

6. Consideration of supplemental lighting. As Glass House expands to new facilities the conversation around supplemental lighting is inevitable. Hopefully this analysis will provide a solid foundation of benchmark to help guide benefit:cost conversations regarding the potential use of supplemental lighting. Glass House is starting at an energy intensity that is almost miniscule compared to the industry average, so even adding some supplemental energy might not compromise it’s standing as an environmental leader.

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[3] https://www.goldstandard.org/blog-item/carbon-pricing-what-carbon-credit-worth

7. Integration of renewable energy, either on-site, off site, or through the purchase of the environmental attributes (renewable energy credits, or “RECs”) from other projects will change the carbon intensity of the electricity used. If renewable energy is incorporated in some manner we would want to re-evaluate the carbon factors used per kWh of electricity use accordingly.