Energy Benchmarking Report

Phase 3 Report - Revised November 8, 2021

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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.

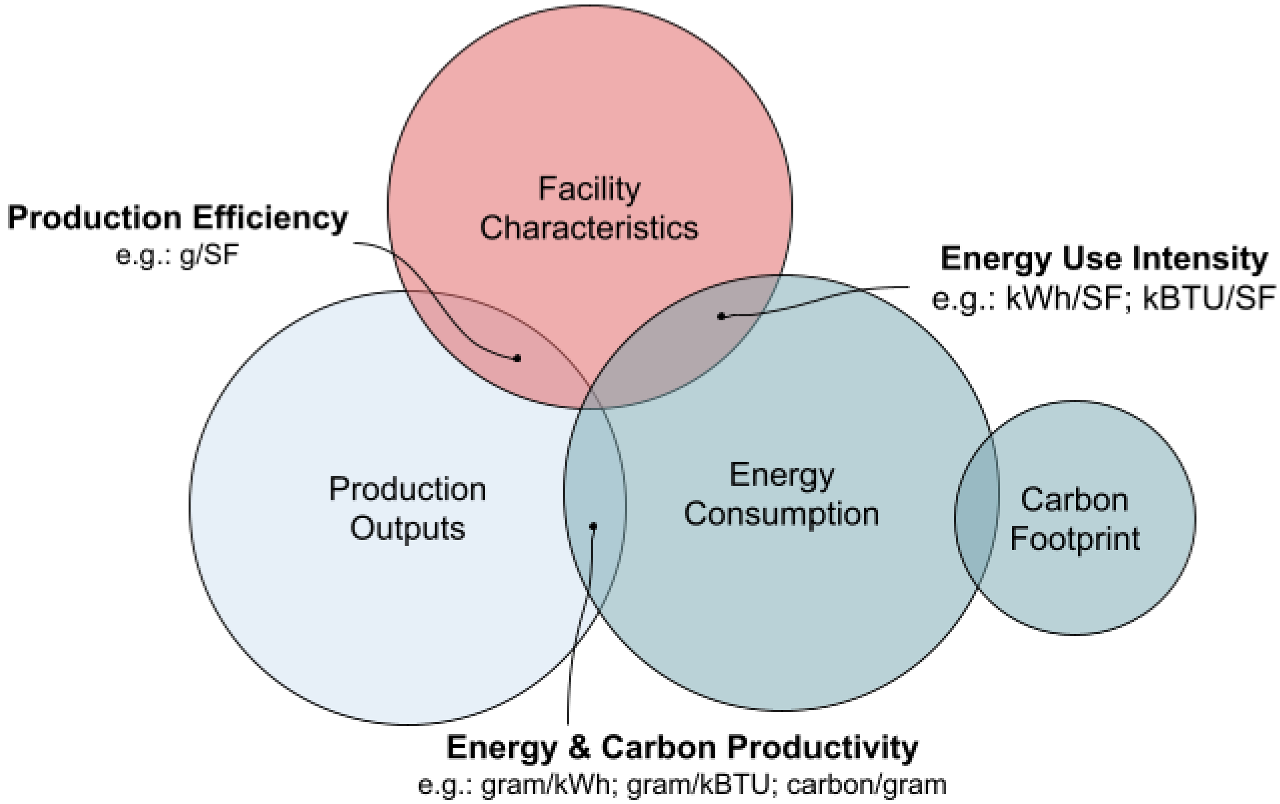
Compared to the best available data for industry averages, Glass House Group's facilities report:

- **Energy Productivity, Electric (g/kWh):** GH yields 5-70 *times* more per unit of electricity used than standard greenhouses.
- **Facility Energy Intensity (kWh/SF) :** GH uses 90% less electricity per SF than typical greenhouses and 95% less than indoor.
- **Production Efficiency (grams/SF):** GH produces **15%-250% more yield per SF** than industry standard greenhouses.
- **Carbon Productivity (kgC02/kg flower):** GH produces **40-55% more cannabis per unit of carbon** than other greenhouses, and **90-95%** more than indoor facilities.
- Glass House Greenhouse operations appear to use **45-80% less carbon than other greenhouses, and 90-98% less than indoor operations.**

Summary: Efficiency Metrics	**Casitas**	**Padaro**	**Glass House Avg.**	**Industry Average, Greenhouse**	**Industry Average, CA Indoor**	**Notes**
Energy Productivity, Electric (g/kWh)	5.3	9.2	**8.2**	1.1	*0.8*	compared to Cannabis Power Score (CPS) data
Energy Productivity, Electric + Gas (g/kBTU)	0.3	0.6	***0.5***	*unknown*	unknown	unknown; CPS benchmark does not include gas
Electric Energy Use Intensity (kWh/SF)	10	14	**13**	134	*262*	per SF of flowering canopy; compared to CPS benchmark
Energy Use Intensity (kBTU/SF)	209	206	**207**	314	*709*	compared to CPS; comparison excludes gas energy
Production Efficiency (grams/SF)	55	124	**107**	48	*174*	Yield per SF of flowering canopy
Carbon Productivity (kgC02/kg flower)	199	87	**101**	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 (Casitas and Padaro) 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		***Casitas***	***Padaro***	***GH Total***
Total Area	*square feet*	142,006	359,997	502,003
Flowering Canopy	*square feet*	90,000	280,000	370,000
Yield, Dry Flower	*grams*	4,957,680	34,703,760	39,661,440
Electricity	*kWh*	19,883,654	66,388,393	86,272,048
Gas	*Therms*	156,692	446,732	603,424
Carbon	*tons C02e*	988	3,272	4,259

Facility Characteristics

Facility Character-istics

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. 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 came from Glass House employee, Philip Van Spronsen, while the flowering canopy square footage is from GH CA State licence capacity. The numbers are are below:

		Casitas	*Padaro*	*Total*
Total Area, SF	*input*	142,006	359,997	502,003
Flowering Canopy, SF	*input*	90,000	280,000	370,000

Production Yields

Production

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 production yields from Casitas and Padaro are based on input from Philip Van Spronsen of Glass House. To arrive at dried cannabis flower yield we began with pounds of biomass harvested per week, applied assumptions of wet weight loss, and converted it to grams of dry flower. The table below summarizes the input and final output values for dried cannabis flower for the two facilities.

Summary: Resource Use, Yields, Facility		*Casitas*	*Padaro*	*Total*
Biomass harvested, weekly, lbs	*input*	3,000	21,000	*24,000*
Biomass harvested, annual, lbs	*calculated*	156,000	1,092,000	*1,248,000*
Dry Flower to Biomass Ratio	*input*	7.00%	7.00%	
lbs of dried cannabis flower per year	*calculated*	10,920	76,440	*87,360*
Grams dried cannabis flower per year	*calculated*	4,957,680	34,703,760	*39,661,440*

Energy Consumption

Energy

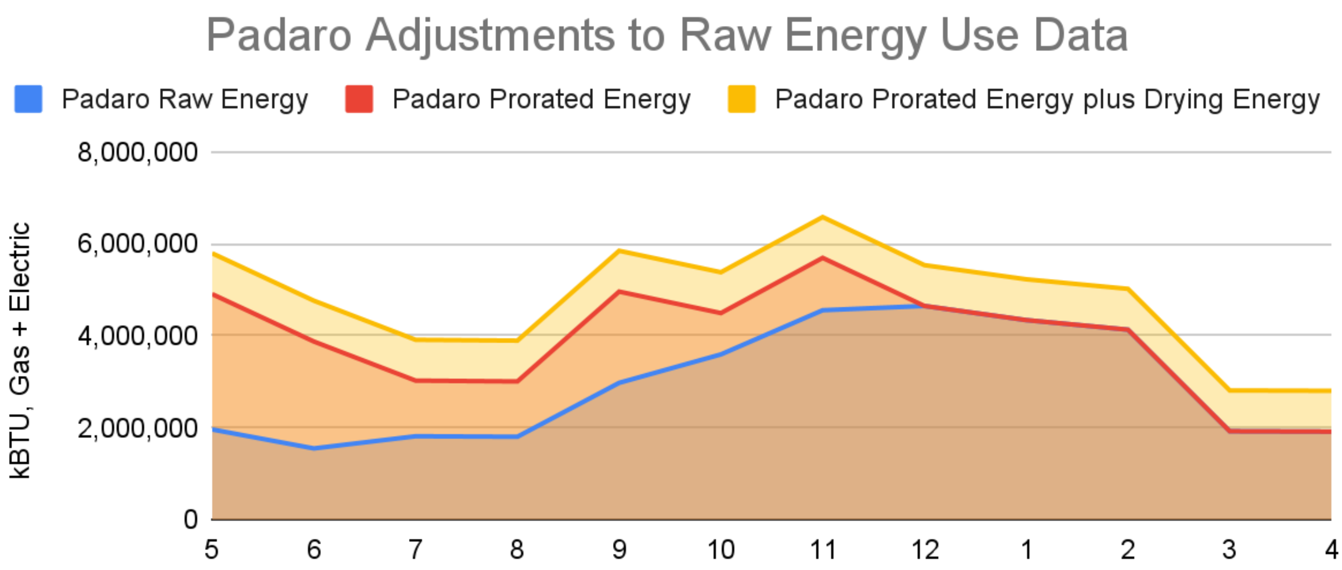
On-site energy consumption is the driving input behind energy and carbon benchmarking for this analysis. The scope of this study is limited to on-site energy consumption from gas and electricity - and does not address the embedded energy in other inputs or transportation or other energy costs associated 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 both electricity and gas consumptions for both of its 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 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. Casitas does dry products on-site, which is a common industry practice. To compare Padaro and Casitas to each other, as well as to other facilities, we added in the expected amount of energy used to dry cannabis for Padaro’s products. Although empirical data about energy use associated with drying cannabis remains elusive industry-wide, 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 on which the 0.09 kWh per gram value was based in Dr. Mills’ 2011 analysis, this value is likely overstated by 100% or more. In other words, even though a modern, commercial scale dehumidification facility would 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 produced by month.

The effects of these two adjustments to the raw Padaro energy data is an increase of 63% 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.

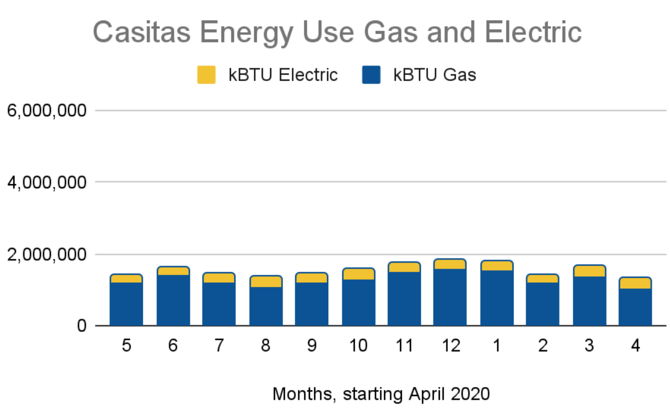


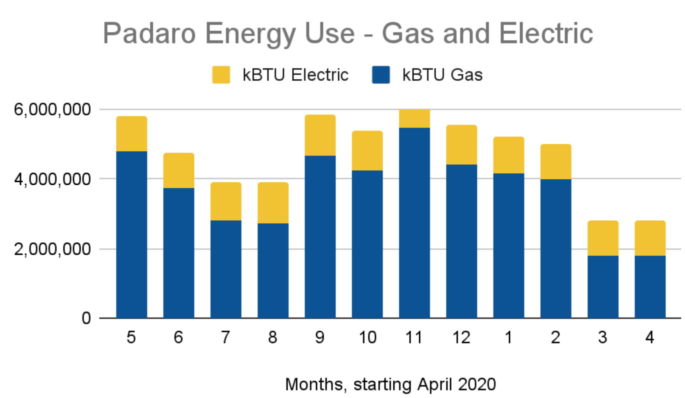
		Casitas	*Padaro*	*Total*
Electric Annual kWh	*input*	931,086	3,787,360	4,718,446
Gas, Annual Therms	*input*	156,692	446,732	603,424

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:

		Casitas	*Padaro*	*Total*
kBTU, Electric	*converted*	3,176,865	12,922,473	16,099,339
kBTU, Gas	*converted*	15,669,200	44,673,158	60,342,358
kBTU, Electric + Gas	*sum*	*18,846,065*	*57,595,632*	76,441,697

Because Glass House's greenhouses require 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.

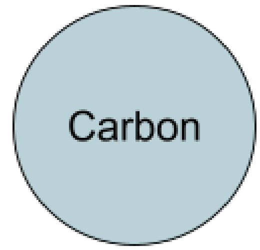




Both sites indicate a heating signature (higher energy use in the heating months), but relatively steady energy use year-round, especially in Casitas where a more efficient hydronic heating system is in use. Also, Casitas includes 3k SF of drying room space; Padaro's drying occurs offsite however the estimated energy impact of the offsite drying is calculated and internalized as on-site energy use for this analysis.

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.



Carbon Footprint

The onsite energy carbon footprint of Glass House's Casitas and Padaro facilities is 3,996 metric tons of C02 annually. Most of this carbon footprint is associated with the use of on-site natural gas for greenhouse heating.

	Casitas	*Padaro*	*Total*
Electric - Mtons C02e	157	640	797
Gas - Mtons C02e	830	2,368	3,198
Total Mtons C02e	**988**	**3,008**	**3,996**

For scale, this equates to the equivalent carbon footprint of 869 US vehicle-years or 481 US household-years.

	Casitas	***Padaro***	***GH Total***
Vehicle-years	215	654	869
US Households	119	362	481

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. Padaro appears to have over twice the productivity per square foot as Casitas.

Production Efficiency	***Casitas***	***Padaro***	***GH Average***
G/SF	55	124	107

[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

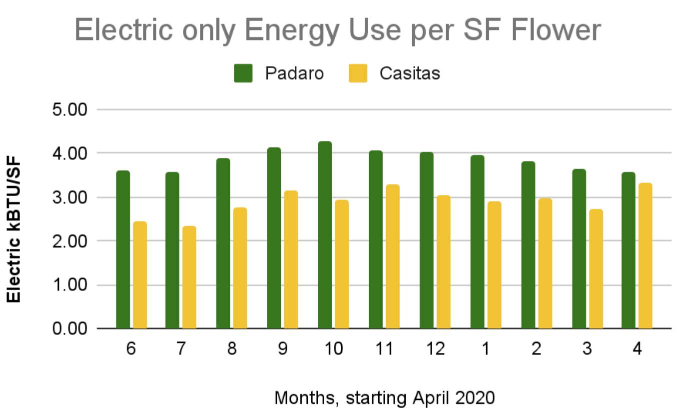
Energy Use Intensity

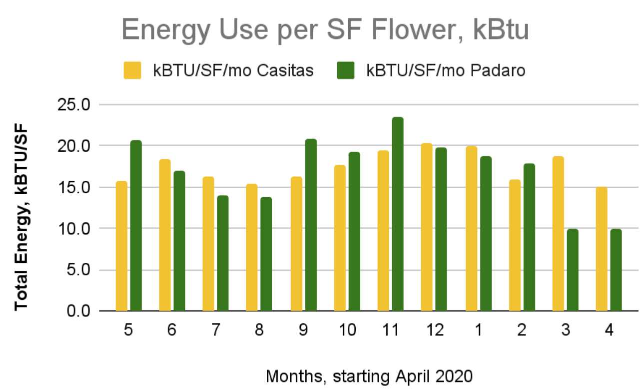
Energy Use Intensity (EUI) is a common metric in the building science and energy efficiency industry. EUI contextualizes energy use to the building square footage - regardless of output. EUI values within the cannabis focus on square feet of flowering canopy only, as this is the driver for revenue. Traditional 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	***Casitas***	***Padaro***	***GH Average***
Annual kBTU/SF Flower	209	206	207
Annual kBTU/SF Total Facility	133	160	152
Annual kWh/SF Flower	10	14	13
Annual kWh/SF Total Facility	7	11	9

The energy usage per SF at Glass House's facilities does fluctuate somewhat throughout the year, as shown in the charts below.





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).

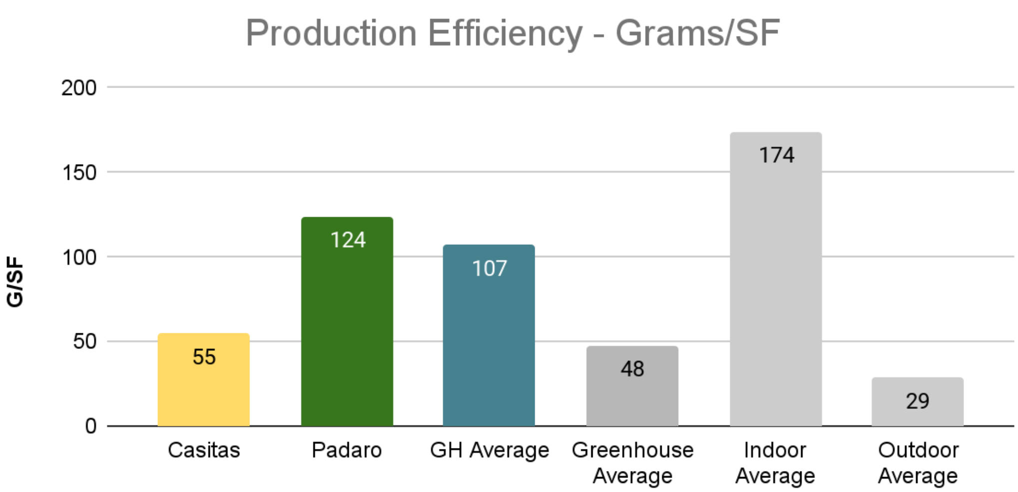
Because so many conversations in the indoor cannabis industry articulate energy use in simple electric terms (kWh/lb), we include both electric on its own as well as electric and gas together. For carbon, the leading metric (popularized by Evan Mills and later by the Summers 2021 report) is "kilograms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

Energy & Carbon Productivity	*Casitas*	*Padaro*	*GH Average*
kWh/lb	85	50	54
kWh/g	0.188	0.109	0.119
kBTU/Gram	4	2	2
Gram/kWh	5	9	8
Grams/kBTU	0.26	0.60	0.52
kG C02e/kG	199	87	101

Industry Comparison - Energy and Carbon Metrics

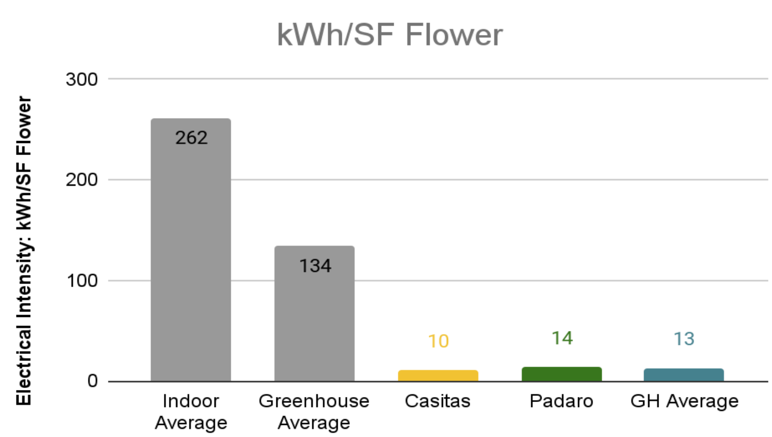
Production Efficiency

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. Whereas Casitas appears to produce about 15% more product than industry self-reported greenhouse averages (from the Cannabis Power Score), Padaro produces approximately 158% more; Glass House facilities' average 123% greater yield per SF than a typical industry average greenhouse.



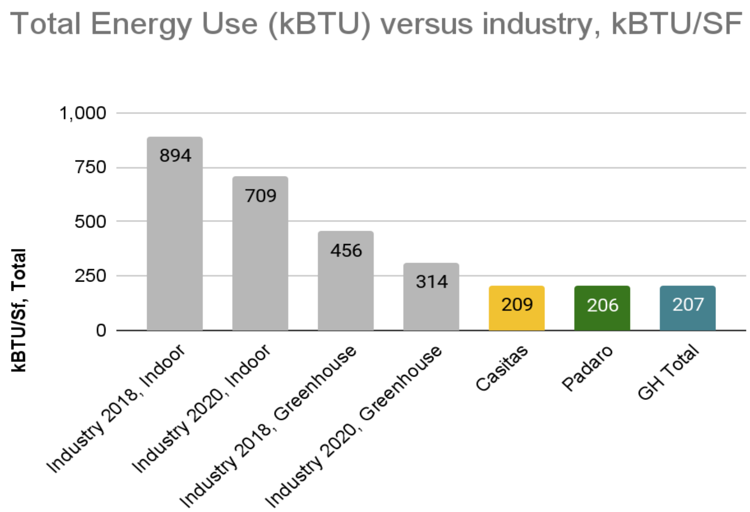
Energy Use Intensity

Compared to industry standard values, Glass House uses 5-10% of the energy use per SF as other greenhouses, and 2-5% of indoor facilities.



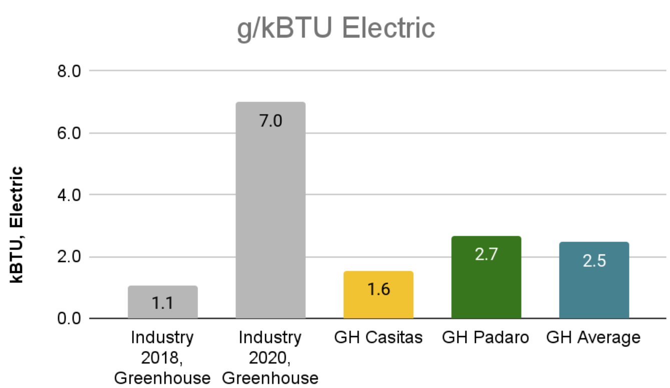
Converting electricity into kBTU Glass House still consumes far less than industry reported values for greenhouse and indoor.

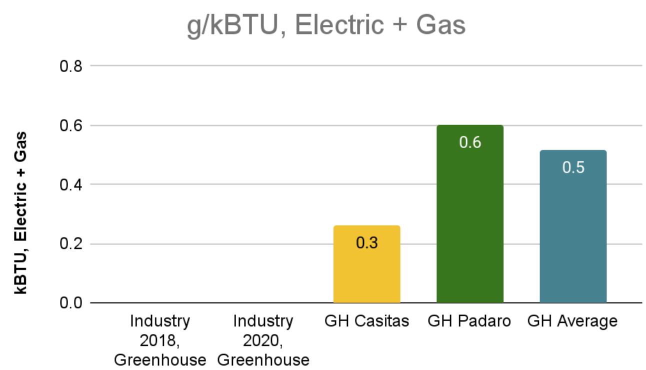
Comparison data is from the Resource Innovation Institute's Cannabis Power Score, which unfortunately is limited to electric only energy consumption.



Energy Productivity

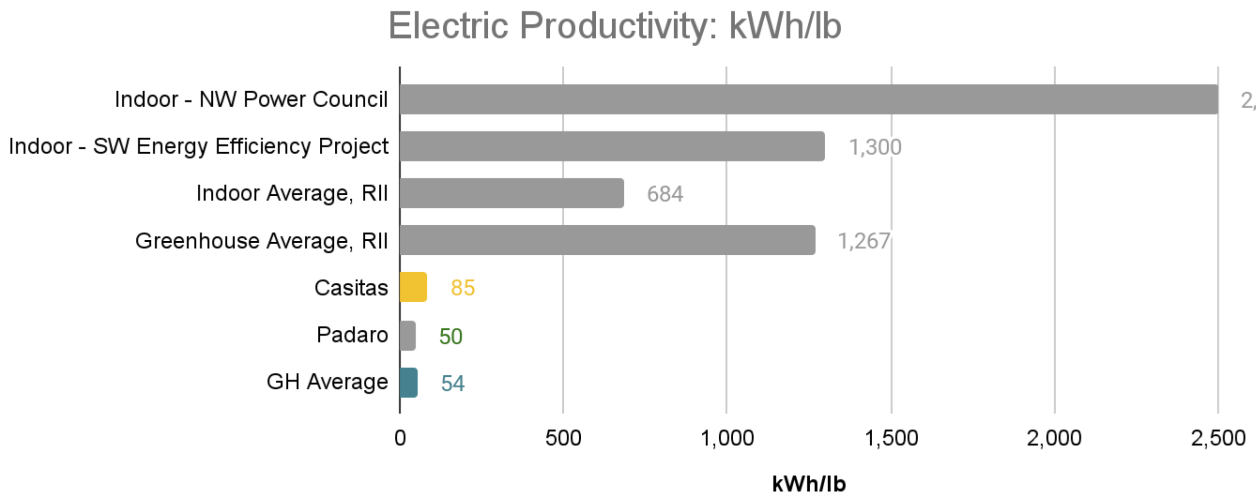
Many metrics for energy productivity were provided above, but grams of yield per unit of energy rises to the top for usefulness. Note that due to a limited data set for the industry at large we can only effectively compare to electric energy; gas energy use is not available. In terms of grams of yield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





kWh per pound of flower is another metric that is discussed in the media. Energy professionals have speculated that between 1300-3000 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 is less than 100 kWh.

The chart below shows 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 1300 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 (transparently or publicly) validate results. However they are shown for comparison purposes nonetheless.



Carbon Productivity

Carbon productivity, or the carbon footprint of the cannabis industry - 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.

Our analysis attempts to contextualize these reports in two steps: first by pro-rating estimated carbon use from an indoor grow within Southern California to a local greenhouse.

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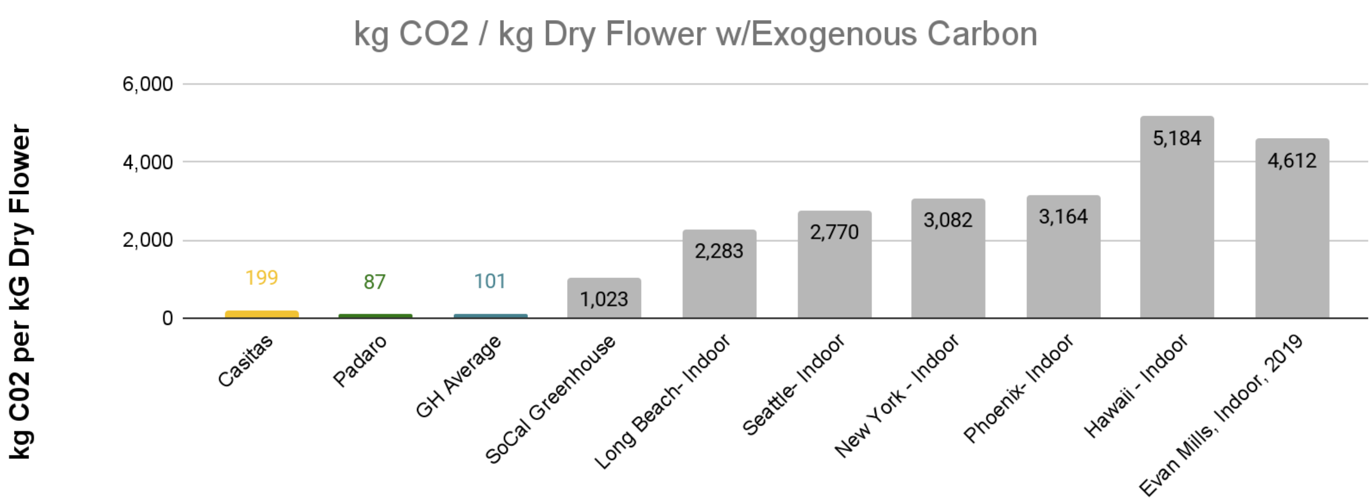
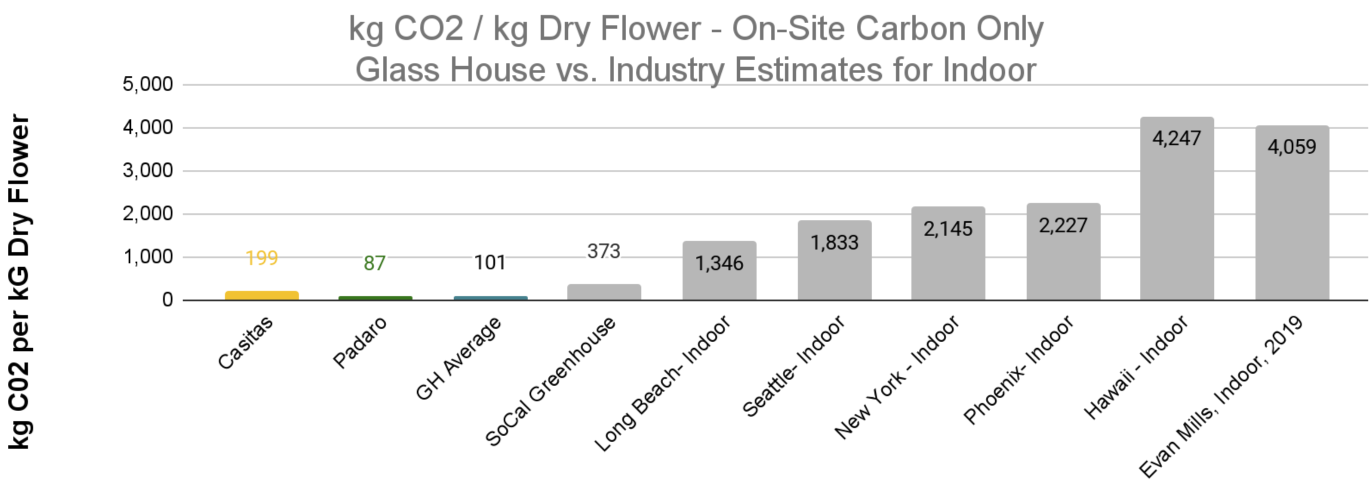


Attempting to remove carbon from variables not associated with on-site energy use, the Glass House carbon footprint (per kg dried flower) looks as follows when compared to the Summers and Mills projections for indoor cannabis.



Recommendations

1. Consider carbon neutrality. If Glass House wanted to purchase carbon offsets to help mitigate its carbon footprint, the cost would be $28,000-$114,000 annually, based on an offset cost of $10-$40/ton.[3] This equates to $0.25-$3.60 per lb of dry flower.

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.

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

4. Disaggregate energy use for non-cultivation end uses. Specifically, Casitas has on-site drying facilities and Padaro does not, thus giving Padaro a relative advantage over Casitas from for energy and carbon metrics. Discussion about whether industry standard includes or excludes these functions will inform whether we isolate and exclude the Casitas drying room energy use from the Casitas numbers, or conversely add (bring into scope) the currently outsourced energy use associated with Padaro cultivation. The impacts of this change are likely immaterial, but will demonstrate a greater level of due diligence and grasp of resource use associated with production facilities.

5. Begin to sub-meter energy and gas uses where 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.

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.