

Cannabis and Climate

The carbon footprint and energy use of indoor cultivation

KEY POINTS

- Environmental impacts need to be taken into account in the cannabis regulation debate, because the high carbon footprint of indoor grow facilities could jeopardize policy aims to meet climate goals
- The carbon footprint of producing 1 kilogram (kg) of cannabis indoors ranges from 2,300 to 5,200 kg CO₂, equivalent to burning 900 to 2,000 litres of gasoline
- The energy used for lighting and environmental controls for indoor cultivation operations can require up to 5,000 kilowatt-hours (kWh) of electricity per kg of dried flower
- For Germany, indoor production of the total estimated amount of 400 metric tons (mt) per year for the recreational market, compares to the total household electricity use of Cologne (Köln), the fourth largest German city with over 1.1 million inhabitants
- The idea that quality and safety standards can only be met by moving cultivation indoors is a myth that pushes legal cannabis markets in the direction of becoming one of the most carbon-intensive industries
- Evidence from practice shows that basic standards can be adequately met in outdoor cultivation, following Good Agricultural and Collecting Practice (GACP) guidelines
- Where domestic climate conditions make outdoor growing more difficult, the best choice would be to allow imports from places with better conditions instead of moving cultivation indoors
- A regulation model that only allows domestic indoor cultivation will increase the carbon footprint and energy use, including in comparison with the current illicit market
- Imports from traditional producing countries would also create legal livelihood opportunities for small farmers currently depending on illicit cultivation
- Given the global climate and energy crisis, there is a compelling case to encourage sustainable outdoor cultivation and to enable certified imports from traditional Southern producers

Environmental impacts are rarely taken into account in the cannabis regulation debate. The assumption is that legal regulation would automatically reduce the negative environmental consequences of the unregulated illegal market, because authorities would compel the industry to comply with basic environmental standards. Practices in North America and the direction of the emerging regulation debate in Germany and other European countries, however, reveal a disturbing trend towards indoor cannabis cultivation. The high carbon footprint of indoor grow facilities could jeopardize policy aims to reduce energy use and to meet climate goals.

Carbon footprint

Depending on the climate conditions, there are a variety of options for cultivating cannabis, ranging from traditional outdoor growing using natural sunlight to windowless indoor sites which require sophisticated technologies to regulate the ambient environment and stimulate plant growth. In the middle of this spectrum are different types of greenhouse structures which may include part-time artificial lighting and other forms of climate control. Sometimes, combinations are used in a single farm, for example mother plants may be kept indoors, while cloning occurs in mixed-light environments, and full plants are grown outdoors.¹

From an environmental standpoint, the distinction between outdoor and indoor growing is significant because of the implications for energy use and greenhouse gas emissions (GHGs). To meet global climate goals, there has been a significant effort to undertake what are known as 'life cycle assessments' to determine the 'carbon footprints' of various industries in order to inform policymaking and climate action. To date, only very limited analysis has been undertaken on this front with respect to cannabis, with the vast majority of research focused on the United States.

A notable early study by Evan Mills in 2012, pre-dating the state-level legalisation of recreational

(non-medical/adult) markets, looked at illegal indoor growing as well as legal indoor production for the medical market. The study estimated that nation-wide, a decade ago, indoor cannabis consumed 20 billion kWh of electricity annually, with additional amounts from direct fuel use, together corresponding to 15 million mt of CO₂ released into the atmosphere each year, an average of 4,600 kg CO₂-equivalent per kg of dried cannabis flower. In California, the top-producing state, indoor cultivation was responsible for about 3 per cent of all electricity use, or 9 per cent of household use: *"This corresponds to the electricity use of 1 million average California homes, greenhouse-gas emissions equal to those from 1 million average cars, and energy expenditures of \$3 billion per year."*²

Over the years, a number of state-level U.S. studies have added to these findings and corroborated the high energy consumption and carbon emissions associated with indoor cultivation.³ One of the most comprehensive studies at a national level is that conducted by Summers et al. (2021) at Colorado State University.⁴ They find that, based on location, lifecycle GHG emissions range from 2,300 to 5,200 kg CO₂ (median value 3,658 kg CO₂) per kg of dried flower, equivalent to burning 900 to 2,000 litres of gasoline.⁵ In some states, this placed the cannabis industry at the top-end of the range of carbon emitting sectors. In Colorado for example, carbon emissions from indoor cannabis production were greater than from the state's active coal mining industry.

The main factors driving up the energy use and GHG emissions from indoor cannabis cultivation include:

- High intensity grow lights which can be 50 – 200 times higher in intensity compared to a standard office setting and which are run for 12, 18 or 24 hours a day depending on the life cycle of the plants;
- Heating, ventilation and air conditioning systems needed to maintain the required indoor temperature and humidity levels;

- Supplemental CO₂ supplies which are added to increase the rate of photosynthesis to allow for quicker and more frequent harvests. This supplemental CO₂ accounts for between 11 – 25 per cent of total emissions across the indoor cannabis industry in the U.S.

In a special booklet on drugs and the environment of the 2022 World Drug Report (WDR), the United Nations Office on Drugs and Crime (UNODC) also underscores the high carbon footprint of indoor cannabis cultivation as one of three main areas of concern.⁶ To illustrate the extremely high emission level per kg of indoor cannabis (2,300-5,200 kg CO₂), comparisons are made with producing one kg of green coffee beans (7 kg CO₂) or cocoa beans (20 kg CO₂). Even after adding international transport, roasting, grinding and packaging, the carbon footprint of a kg of coffee grown in South America and sold in Europe is not more than around 15 kg CO₂.⁷

While steps can be taken to maximise efficiencies in indoor operations by, for example, encouraging the use of more efficient LED lighting, this still ‘optimises the suboptimal’ as the carbon footprint of indoor cultivation remains many times higher than that of outdoor growing. Gains that can be made by introducing energy saving technologies are relatively minor. The same applies to the assumption that high energy demands can be compensated by switching to renewable energy sources after efficiencies have been maximised. According to Mills (2022) *“an intractable structural problem for energy-intensive indoor cannabis production is that less than one-tenth of all energy needs (even less in the case of more ‘efficient’ vertical cultivation) can be generated by placing solar arrays on a typical facility’s rooftop, even in locations with ideal solar resources”*.⁸

Some cannabis companies have released ‘Environment, Social, and Governance’ (ESG) reports, and expressed support for net-zero energy goals, but *“they have not acknowledged the practical impossibility of doing so indoors”*.⁹ Despite decades of experimentation and technological innovation, *“scalable solutions to the sticky energy and carbon problem have still*

not been demonstrated”.¹⁰ The best-case scenario rests with outdoor cultivation, which is *“the most technologically elegant, sustainable, ethical, and economically viable approach for minimising the rising energy and environmental burden of cannabis production”*.¹¹

Energy consumption

In 2020, the National Cannabis Industry Association reported that 63 per cent of commercial cultivation in the U.S. takes place indoors, and another 20 per cent in mixed-light greenhouse settings. *“The energy used for lighting, environmental controls, and hydration at indoor cultivation operations can require up to 5,000 kilowatt-hours [kWh] of electricity per kilogram of output”*, according to the industry’s own estimate. They recommend therefore, that: *“Notwithstanding the benefits of greenhouse and indoor cultivation, outdoor cultivation should be encouraged to the extent practical because of the significantly reduced energy intensity of outdoor cultivation.”*¹² The difference in terms of energy use between indoor and greenhouse cultivation is difficult to quantify. Per square meter, greenhouses use much less electricity for lighting, but because of lower yields the savings per kg of cannabis produced are probably not more than around 25 per cent, according to one study in the U.S. based on limited data.¹³ Greenhouses also rely more often on natural gas for heating, so studies primarily looking at electricity use may underestimate total energy consumption.

Also for indoor growing, the amount of kWh/kg varies significantly depending on outside temperature and humidity, the efficiency of used equipment, and the method of calculation. A report published by the Colorado Energy Office in 2018, for example, mentions a lower figure of 2,650 kWh/kg based on self-reported data from three indoor grow operations in the state.¹⁴ The earlier quoted studies by Summers et al. and Mills, however, using a more comprehensive methodology, confirm the order of magnitude under less favourable conditions, with estimates up to 4,600 and 6,000 kWh/kg respectively. Similar

levels are confirmed for small-scale 'home grow' tents: "A fully fledged indoor grow-op in a small 1.2x1.2x2.4m grow area will consume about 13,000 kWh of electricity a year".¹⁵ Based on an average yield of 500-575 gr/m² per yield, as estimated in Dutch and Belgium studies,¹⁶ and 3 to 4 yields per year, that would also range between 4,000 to 6,000 kWh/kg.

Applying these estimates to Germany reveals a dramatic picture of potential environmental impact and energy consumption, the consequences of which have thus far largely been absent in the policy debate on the announced legal regulation. Germany has a population of 84 million people, more than twice the size of Canada or California. A calculation by the Düsseldorf University of the fiscal impact of a legal cannabis market in Germany estimated the total annual demand for adult use to be around 400 mt.¹⁷ Multiplied by the average of 5,000 kWh/kg, producing that full amount indoors in Germany could require about two million megawatt hour (mWh) of electricity. To put that in perspective, the average electricity consumption per household in Germany is about 3,100 kWh per annum.¹⁸ Indoor production of the required amount of 400 mt, would be comparable to the total household electricity use of a city like Cologne (Köln), the fourth largest German city with over 1.1 million inhabitants and an annual consumption of 1.9 million mWh.¹⁹

Of course, not all of that would be additional energy use when the market is legally regulated. There is already significant indoor cultivation in Germany now to supply the illicit market. There are no reliable estimates of the share of illegal cannabis imports within the German market, and even less is known about how much of that import is cultivated outdoors. Herbal cannabis seized in Germany, however, mostly originates from Albania, and hashish primarily originates from Morocco.²⁰ A substantial part of the supply for the adult market, however difficult to quantify, currently comes from countries where it is grown outdoors by small farmers. Although the objectives of the intended regulatory framework appear to focus mainly on health issues and

product safety, environmental impacts cannot be left out of the equation. The regulatory framework should also aim to limit as much as possible the carbon footprint by favouring more sustainable production sources, including in comparison with the illicit market. A regulation that only allows domestic indoor cultivation will do the opposite and only increase the carbon footprint and energy use.

The case for outdoor cultivation

There is a strong case to be made for cannabis cultivation for the regulated market to be based on outdoor cultivation in light of the vastly reduced carbon footprint. In the U.S., licit outdoor cultivation is still stymied by a number of regulations. Co-location requirements – the requirement that cultivation and retail along with the needed infrastructure take place in close proximity to one another – as well as licensing regimes that set fees according to the size of the area under cultivation incentivise indoor growing as yields can more easily be maximised per square foot indoors. A number of other measures, such as the offering by utility companies of energy-saving rebates and cheap industrial rates to indoor growers, tip the balance in favour of indoor cultivation. Most cultivators in those states *"will be growing cannabis indoors because of climate, regulations or individual business preferences, laying the groundwork for skyrocketing electricity consumption created by the new markets"*.²¹ Meanwhile, U.S. federal cannabis prohibition thus far disallows inter-state commerce which would enable locating cannabis production in regions suitable for outdoor growing.²²

The ultimate form of 'geographic optimisation' would be to prioritise and regulate cannabis cultivation within traditional producing countries of the global South where the vast majority of cannabis is cultivated outdoors. Legal international trade in cannabis especially for recreational markets, however, is still extremely complex and requires resolving international legal obstacles. Even for the medical cannabis market, the difficulties in obtaining import and

export licenses mean that still relatively limited cross-border trade has taken place thus far, and hardly any from traditional Southern producers to Northern markets. Germany, for example, imported a total of 20.6 mt of medical cannabis in 2021, primarily from Canada, Denmark, the Netherlands, Portugal and Australia.²³

Cannabis regulation has advanced more rapidly in the global North, and this confers significant 'first mover' advantages to investors from these countries in the global cannabis market. It is not coincidental that many of the world's largest cannabis companies that dominate the industry are Canadian. The corporate capture of the medical cannabis industry could repeat itself in the emerging recreational markets where countries in the global North have favoured an import substitution approach to avoid additional legal hurdles, foreclosing developmental opportunities in principle available through (fair) trading relationships with Southern countries.²⁴ As Kenza Afsahi (2020) argues: *"Changes in cannabis regulation are intended to control cultural, environmental and social justice abuses, but the cannabis market currently has relatively few economic models that promote justice, respect for the environment and equity between South and North and rich and poor."*²⁵

Despite the appearance of various voluntary certification schemes and 'eco-labels', there are no safeguards against 'greenwashing', the practice of companies making false environmental claims for marketing purposes. These touch on issues related to the responsible management of land and water resources; energy use and emissions; chemical use and disposal; plastic waste; odour pollution and air quality; and the provision of inaccurate, misleading or otherwise unverifiable information on environmental sustainability.²⁶

Outdoor compliance with quality standards

There is no doubt that outdoor cultivation poses additional challenges for product standardization and quality control, the argument most often

used to defend indoor cultivation. Illegal outdoor cultivation in traditional Southern producing countries have also been associated with significant environmental problems. The influx of foreign strains with higher yields and THC content, for example, has led to increased use of pesticides, artificial lighting in Colombia and to water depletion, soil erosion and land degradation in Morocco. Law enforcement and eradication operations have moved illicit cultivation to more isolated places, including into protected areas, sometimes leading to deforestation, as happened in Nigeria.²⁷ Outdoor cultivation is also more vulnerable to weather conditions, and cross-pollination can lead to the degeneration of cultivars. Adapting current illicit growing practices to the standards required in legally regulated markets is certainly not an easy transition. But the idea that these problems can only be resolved by moving cultivation indoors is a myth that pushes legal cannabis markets in the direction of becoming one of the most carbon-intensive industries.

There is enough evidence from practice that basic quality and safety standards can be adequately met in outdoor cultivation for adult as well as medical use. The only federally licensed producer of medical cannabis in the U.S., for example, cultivates most of its plants outdoors.²⁸ Colorado is one of the few states that allows consistent outdoor cultivation at scale.²⁹ In Canada, where initially all production of medical cannabis took place indoors, the first outdoor licenses were granted in April 2019 after the legal regulation of the adult market. By April 2021, Health Canada had granted 110 outdoor cultivation licenses across the country, the majority for the adult market but also several for medical purposes.³⁰ There are several other countries, including Portugal and Australia, where licensed outdoor cultivation for medical use is taking place.

Both the World Health Organisation (WHO)³¹ and the European Medicines Agency (EMA)³² have developed Good Agricultural and Collecting Practice (GACP) guidelines for plant-based medicines, most of which are grown outdoors. Special GACP protocols for medicinal plants have

also been established under the Pharmaceutical Inspection Co-operation Scheme (PIC/S).³³ A Cannabis Expert Panel evaluated specifications for United States Pharmacopeia (USP) quality standards for medical cannabis to mitigate public health risks associated with contaminated, substandard, or adulterated products.³⁴ And the Cannabis Committee of the American Herbal Products Association (AHPA) elaborated best practice rules from seed to sale for safe and responsible medical and adult use.³⁵ The recommended standards apply to indoor as well as outdoor cultivation, and there is no suggestion that compliance with the rules could only be achieved by controlled indoor cultivation. If it is possible to comply with the high standards for medical use, quality and safety guarantees can surely be met in outdoor growing for recreational markets, in compliance with GACP and Good Manufacturing Practice (GMP) guidelines.

Imports from traditional producing countries

Where domestic climate conditions make outdoor growing more difficult, like in northern Europe, the logical choice would be to allow imports from places with better conditions —as happens with coffee, tea, cacao and many other agricultural products— instead of moving cultivation indoors. The carbon footprint of transport from those regions would only represent a tiny fraction of the emissions related to indoor grow facilities. In the case of coffee, for example, the emissions of freight flight transport per kg from Brazil or Vietnam to the UK are around 11 kg CO₂, and by cargo ship no more than 0.2 kg CO₂, negligible amounts compared to the carbon footprint of indoor cannabis.³⁶

In Germany, the fact that most of the supply is still coming from abroad five years after the legalisation of medical cannabis, indicates that it will be hard to fully meet the much larger recreational demand by local production alone. The German cannabis industry association BvCW *“advocates the creation of a regulatory framework that enables market access for products from*

*German cultivation, as well as the import of products from countries with comparable quality standards. [...] Despite concerns about compatibility under international law, the BvCW supports the creation of opportunities for international product imports.”*³⁷ Also the German Hanfverband (DHV) argues: *“Import from other countries - including traditional production countries such as Morocco, Afghanistan, Nepal, Lebanon, etc. - should be possible, provided that corresponding official regulations exist there in the future”*.³⁸

Allowing imports from traditional producing countries would also be in line with Germany's long-standing support for a development-oriented approach to drugs policies, aiming to create alternative legal livelihood opportunities for small farmers.³⁹ This is crucial to prevent millions of people whose livelihoods depend on the illicit cannabis market from being left behind in the transition to legal regulation.⁴⁰ On both ends of the supply chain obstacles in international law indeed need to be addressed, but legal solutions that can be found to justify domestic production can also serve as a basis for legitimate trade arrangements.⁴¹

All of the above adds up to a compelling case to encourage sustainable outdoor cultivation (or in some cases greenhouses as a second-best option) and to enable certified imports from traditional Southern producers. As the experts in this field conclude, the best option to reduce carbon emissions and energy use is *“avoiding the practice of indoor cannabis cultivation altogether”*.⁴² *“In a warming world, indoor cultivation is an unessential and unaffordable luxury”*,⁴³ especially for the non-medical market.

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