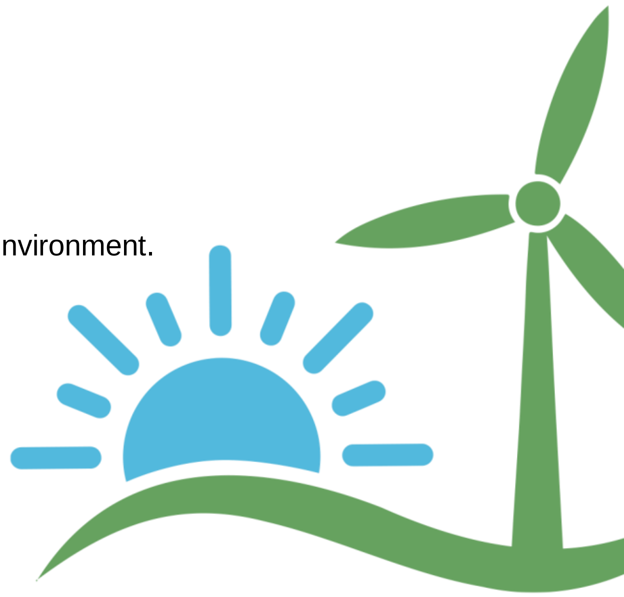
# Being Carbon-Negative

– Carbon does not mean carbon and how we will help the environment.



**Public Document**



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## Introduction

Glass Pharms® is on a mission to underpin the UK cannabinoid medicines market with affordable high quality products. We are also passionate about doing so in a way that makes a positive contribution towards reducing climate change.

This whitepaper sets the scene about what carbon negative really means and some of the ways we are protecting our environment as we produce our product.

## Carbon ≠ Carbon

When it comes to being carbon neutral or carbon negative “carbon” does not equate to atoms of elemental carbon. We use carbon as a shorthand for eCO2, a unit of measure for Global Warming Potential (GWP) established by the Intergovernmental Panel on Climate Change, used globally since the Kyoto Protocol of 1997. $CO_2$ was chosen as the reference gas when assessing the potential of various gasses that contribute to global warming as one of the least potent and most prevalent.

*Table 1 GWP[1] values by greenhouse gas, excluding climate change feedback*

| Gas | $GWP_{100}$ |
|---|---|
| **Carbon Dioxide, $CO_2$** | 1 |
| **Methane, $CH_4$** | 28 |
| **Nitrous Oxide, $N_2O$** | 265 |
| **Tetrafluoromethane, $CF_4$** | 6,630 |

Greenhouse gasses work by absorbing heat, in the form of various wavelengths of light and retaining this heat in our atmosphere, rather than that light being lost to space.

One can see from Table 1 that removing one molecule of nitrous oxide from the atmosphere would be equivalent to 265 $CO_2$ molecules and would be highly “carbon negative” even though there are no carbon atoms involved. Not all carbon-based gases are created equal. Tetrafluoromethane ($CF_4$), for example, is equivalent to 6,630 $CO_2$ molecules and is also highly stable creating a greenhouse effect for 50,000 years compared to methane’s ($CH_4$) $eCO_2$ of 28 which survives a more modest 11.8 years before it typically gets oxidised to $CO_2$. It is easy to understand why fluorinated hydrocarbons have been phased out of refrigerants.

[1] Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

## Choosing an Energy Source

Without undertaking the complexities of assessing the construction of the generation facilities themselves, let's look at various sources of energy one could use to power operations.

### Carbon Generative

The industrial revolution was fuelled by coal and our modern lives are still heavily dependent on fossil fuels, which are all hydrocarbons of some variety. A combination of carbon and hydrogen atoms forming molecules of different weights and ratios. They are burnt using atmospheric oxygen to form oxides of carbon and water. Depending on the purity of the hydrocarbon source and the burning conditions, a whole host of other pollutants can be created such as oxides of nitrogen and sulphur or particulates.

We have seen that nitrous oxide, (one of the oxides of nitrogen) is a potent greenhouse gas, but the primary greenhouse gas by volume produced is carbon dioxide.

Burning fossil fuels is highly carbon generative.

### Carbon Neutral

During this century and the last, man has devised indigenous methods of generating electricity without operational creation of greenhouse gasses. These include solar panels, wind farms, tidal and nuclear fission. These methods can generate electricity without $eCO_2$ emissions and are hence carbon neutral.

Hopefully, this century, we will see nuclear fusion providing a clean source of power also.

### Carbon Negative

"How can one generate electricity in a carbon negative way?", I hear you ask. We have previously seen that not all carbon is created equal.

The UK alone produces 9.5 million tonnes of food waste, the vast majority of which goes into landfill. As the food decomposes, it creates both methane and $CO_2$. According to DEFRA about 36% of methane is now recovered from landfill, but it is still a significant pollutant. Adjusted for landfill recovery, methane from food waste has a $eCO_2$ of 18 in the UK.

If we can avoid methane from entering the atmosphere we can be carbon negative, even just by converting it to $CO_2$, despite there being the same amount of elemental carbon. We can do this using an anaerobic digestor.

Anaerobic digestors convert waste food into biogas; a mixture of $CO_2$ and methane. For every methane molecule converted to $CO_2$ we save 27 equivalents of $CO_2$ or 17 when one adjusts for landfill recovery. The digestate from our digestor is spread on the fields as a soil improver and our waste material can be put back in the digestor with the waste food. There is also waste hot water from the process which we use for both heating and cooling applications at our glasshouse.

Anaerobic digestion represents a highly symbiotic and environmentally responsible energy source for us.

# Choosing a Growing Environment

When establishing a new cultivation, one is presented with a number of options:

## Outdoor Growing

Our most familiar view of agriculture is growing outdoors in fields. Outdoor growing relies solely on light from the sun. This widespread technique requires the grower to plant and harvest in step with the seasons, This limits when plants can be sown and harvested and how many harvests can be made, typically one per year for our crop. Moreover, the consistency of the plants varies from year to year depending on the year's weather, like vintages of wine varying in quality from year to year. This cannot meet pharmaceutical tolerances unless the flower is only used for extracts.

## Indoor Growing

The antithesis to outdoor growing, where one is at the mercy of the elements, is indoor growing where everything is controlled by the grower. As covered, in the next section, this technique comes at a premium, as one forsakes nature's gift of light for artificial light. Indoor growing delivers on control and consistency but not on energy efficiency. Vertical growing is not suitable for plants of 1.5m height such as ours, except for juvenile plants; a technique we employ.

## Glasshouse Growing

There are accounts of the Roman's creating glasshouses in the 1$^{st}$ century AD to supply emperor Tiberius with cucumber-like vegetables throughout the year. Using nature's light was supplemented with artificial light in the 1960s. Glasshouses offer the prospect of growing throughout the year, but controlling the climate in traditional glasshouses is challenging and energy hungry. Traditional glasshouses struggle with overheating in the summer and heating in the winter. It is also difficult to control humidity and air flow. These pressures are typically overcome by using natural gas powered heaters, horizonal fans, fogging systems and HVAC units. Even with the extra measures in place extreme diligence would be required to achieve EU pharmaceutical tolerances for *flos.*

## Next-Generation Glasshouse Growing

The latest generation of glasshouses seek to address the shortcomings of temperature and humidity control. Semi-closed glasshouses turn traditional glasshouse cultivation on its head requiring growers to relearn how to grow. Climate is controlled using a climate chamber which preconditions air introduced into the glasshouse. Air flow is assisted by a convection current created by air flowing back into the climate chamber as well as fans generating vertical air flow rising from beneath the plants. Climate management is sufficiently complex to require a computer to manage it. Artificial intelligence has made an impact in this area, taking weather forecasts into account to use the correct level of expensive artificial light and monitor plant growth and nutrition. This revolutionary step forward in glass house technology allows close control of the climate throughout the year, harnesses sunlight and minimises energy consumption compared with traditional glasshouses. We believe this level of control is vital to provide a consistent high quality product, with a responsible carbon footprint, to the pharmaceutical industry.

## Smart Technology at Work

Glass Pharms has employed some of the most advanced glasshouse technologies in the world. We have done this to deliver a consistent environment for our plants throughout the year, which in-turn helps deliver consistent product.

### Water

In the year this whitepaper was written agriculture was hit hard by drought, affecting yields or causing crops to fail. Water is becoming an increasingly important resource to manage. Our facility captures all the rainwater that falls upon it and stores it in covered storage tanks with over 2 million litres of capacity. We use this water for all agricultural activities and recirculate the water within the environment, using UVC light to sterilise. We do not use any mains water at all.

### Power Consumption

Our facility saves energy in a number of areas compared to an indoor grow facility, resulting in approximately 45% of the overall energy consumption.

### Heating & Cooling

Most commercial glasshouses use natural gas (fossil based methane) as a source of heat. In our industry they typically have high energy hungry mechanical air conditioning, HVAC, units to deliver the cooling required for dehumidification. We use the waste water from the anaerobic digestor to heat our environment and condition the air feed into the glasshouse. Using waste heat avoids us having to use natural gas or other fuel to heat-power our facility and our innovative system avoids using large amounts of electricity for dehumidification.

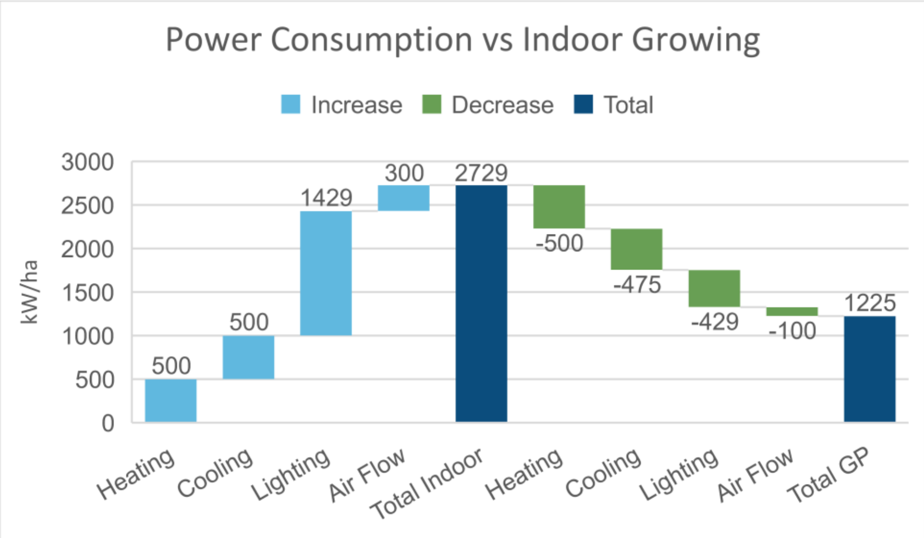


*Figure 1 Approximate energy use comparison to indoor growing*

### Lighting

Historically agriculture relied solely on the light from the sun. GE first developed high pressure sodium lights in 1962, which have been deployed in agriculture ever since. More recently alternative technologies have been developed, including LED lights for agriculture with light spectra that can be tuned to the requirements of the grower. LED lights are much more efficient, using up to 70% less energy than traditional technologies and becoming better every year, but nothing beats free light from the sun, which is why we don’t grow indoors. 30 – 40% of our light will come from the sun representing a big saving over the course of a year. In the past agricultural lights were either on or off but this results in either too much or too little light. Dimmable LEDs now allow precise dosing of light, eliminating waste.

Our plants like intense light and lighting is the single biggest use of electricity in the facility. We measure the light hitting the plant canopy from the sun and supplement it with artificial light as required, so that over a given week the plants always get the same amount of light. AI assists us in making light intensity decisions, looking at weather forecasts for our location and automatically compensating for improving or deteriorating sunlight over the course of the week ahead.

### Air Flow

Airflow is important for plant gas exchange and transpiration. We use energy efficient fans to get air moving but our design has the benefit of a convection current to naturally take the air to where it is needed. All our air is preconditioned in a computer-controlled climate chamber that mixes the right amount of external air with recirculated air to keep climatic conditions consistent in the glasshouse and minimise energy consumption required for heating or cooling.

### Security

Yes, even our security is energy efficient. We employ security cameras with thermal imaging, that avoids us having to flood light at night and this also avoids light pollution.

## Carbon Sequestering

Our crop is one of the most effective at sequestering carbon. As plants grow they absorb atmospheric $CO_2$ and convert it to sugars which are then used by the plant to grow and produce a myriad of compounds. It is a very complex area to calculate, but for comparative purposes, our crop is more than twice as good a sequestering carbon compared to trees at between 8 to 15 tonnes of $CO_2$ per hectare per year, versus trees at around 2 to 6 tonnes of $CO_2$ per hectare per year depending on the number of years of growth, climatic region and type of tree[2]. Were we to be using grid electricity, that would be enough to offset around 78 MWh or 21 average households electricity use per hectare of growth.

## Conclusion

We believe our combination of energy source and advanced technology will provide a sustainability benchmark for protected agriculture worldwide. We have combined the yields and control of indoor growing with our next-generation glasshouse, harnessing AI. Our energy saving technology uses 45% of the power compared to indoor growing. We carefully recycle our water, fix $CO_2$ with our crop and provide a soil improver to our neighbouring farm. There is no better way to grow to meet the exacting quality standards that patients require and the tolerances required by the EU & UK pharmaceutical industries.

[2] https://www.dezeen.com/2021/06/30/carbon-sequestering-hemp-darshil-shah-interview/