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P5_3 Exhaust-ing Gardening

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Abstract

In Series 13, Episode 5 of Top Gear, Jeremy Clarkson decides to help stop global warming once and for all. He designs a system in which a car tows a greenhouse full of plants in an effort to completely offset Carbon emissions. This report contains the physics required to obtain an accurate comparison of both emission and sequestration rates. This data has been used to acquire a well-based estimate of the number of Bamboo plants required to achieve this neutrality. This value comes out to be 125 stems, which would likely result in a greenhouse 78 m long, assuming all the plants are equal in size. We therefore conclude this system would not be feasible.

Introduction

During Series 13 Episode 5 of Top Gear [1], Jeremy Clarkson proposed an idea which would surely revolutionise the way we deal with Carbon emissions from cars. His example involved a 2005 4.4L Range Rover Vogue with a greenhouse full of tomato plants towed behind it. A pipe was installed connecting the exhaust to the greenhouse. The idea was that if you divert all of the exhaust fumes from the car, into the greenhouse, you could counter the CO_2 production with enough plants, effectively making the vehicle carbon neutral. Unfortunately for Jeremy the greenhouse shattered and collapsed after only a few metres on the road. The question is: If it were able to stand, could this really work?

Method

We begin by assuming that the plants are under their ideal growing conditions, to maximise the amount they grow each day. Clearly, the system can be considered carbon neutral if ALL of the CO_2 produced by the car is absorbed by the plants. The conclusion of viability can therefore be drawn by comparing the two values.

The premise behind this idea is a process called Carbon sequestration which involves removing Carbon from the atmosphere and storing it in places such as plants. We started by finding the emission statistics for the car that Jeremy used in his example and found them to be 352 g/km of CO_2 [2]. To convert this into a rate of CO_2 released per hour, we assumed an average speed of around 50 km/h for standard driving. This emission value is the mass of Carbon Dioxide released, however, we needed to find the mass of just Carbon, to know how much needs to be sequestrated per hour. We found this by multiplying by the mass contribution of Carbon to each CO_2 molecule: $m_C = \frac{12}{44} \times m_{CO_2}$. This gave us a mass of Carbon released of 4.8 kg/h when travelling at 50 km/h, and therefore the plants will need to absorb this amount to ensure the system is Carbon neutral.

To give this method the best possible chance of success, we wanted to use a plant that grows at a very fast rate so that as much Carbon is absorbed as possible. The best candidate we found for this was Bamboo, as some species hold the Guinness World Record for the fastest growing plants in the world at up to 91 cm per day [3]. We found the additional mass of bamboo this would correspond to by calculating what volume this growth rate would produce. We found values for the average diameter and thickness of bamboo to be: 108 mm diameter and 11.1 mm thickness [4]. We used these numbers to calculate the volume of bamboo by treating it as a hollow cylinder. We did this using the equation below:

$$V = h\pi \left(\frac{D}{2}^2 - \left[\frac{D}{2} - T \right]^2 \right) \tag{1}$$

Where V is volume, h is height of growth, D is diameter, and T is thickness. The volume this gave us was 1.28×10^{-4} m^3.

We then found the average density of bamboo which was given as a range from 0.54 to 0.78 gcm^{-3} [5]. We used the midpoint of this range for our calculations and, when substituting into $m = \rho V$, we found the additional mass of bamboo per hour to be 0.084 kg/hr.

Not all of this mass will be pure Carbon however, and to account for this we needed to find the Carbon content of the plant. We found values for the root, leaf, and stem [6], and averaged these to find a Carbon content of 45.8%. When we multiply our mass by this percentage, we find the mass of Carbon removed to be 0.039 kg/hr per stem of bamboo.

The final step of the calculation was then to divide the Carbon released from the car by the Carbon absorbed by each stem of bamboo to find the number of stems required for total offset of Carbon.

Results and Discussion

The final result we found was that 125 stems of bamboo would be needed to offset the CO_2 released by the Range Rover, if ideal growing conditions for the bamboo are assumed.

If we use the average diameter of bamboo, allow 30 cm between plants, and assume 4 stems can fit within the width of the car, we find that the greenhouse would need to be around 78 m long.

Conclusion

When this result is combined with the obvious need to cut the bamboo every day to stop it growing out the top of the greenhouse, we can conclude that this is not a viable option to negate the CO_2 released by a car.

References

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