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P5_7 Baked Alaska

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Abstract

Alaska currently has a very cold Arctic and sub-Arctic environment, but due to global warming and a proposed increase of global temperatures of 5.4 °C by 2100 AD this is being threatened. We calculated if placing an insulating cube on Alaska in 2100 AD and using a refrigerator to cool it down to its 2019 AD temperatures was a viable solution to keeping Alaska cold. It was worked out it would need 1.1×10^{21} J of work in order to cool the interior of the cube. It was concluded the environmental damage and increased fossil fuel emissions are too great for this to be a option.

Introduction

Climate change is a threat to the boreal forests and perma frosts in Alaska. There are many forecasts as to how severe the mean global temperature increase will be, however it is often placed between 1.1 °C to 5.4 °C by 2100 AD. [1]

Alaska is the northern most US state and is the largest, with a area of 1530000 km^2 with diverse environments and wildlife and an average temperature of 2.8 °C. [2] The US government needs to know how much energy it would take to cool Alaska down to its current conditions in 2100 AD, so while the surroundings heat up Alaska internally can remain cold.

Theory

This shall be achieved by creating a cuboid from sea level to 10 km high which has a length of 3639 km and a width of 2285 km, covering all of mainland Alaska. The Earth is a sphere but due to the fact we are only focusing on a very small part of the Earth's surface, the curvature can be ignored and assumed to be flat. The volume of this cuboid is approximately 83×10^6 km^3 and for this report is assumed to be filled with air with the density and pressure of dry air at sea level.

The cuboid is constructed as to be a perfect insulator, meaning the cuboid is adiabatic with no energy transfer to or from the outside only via the refrigerator engine that will be used to cool it. The outside temperature increase caused by climate change shall be assumed to be the worst case scenario of an increase of 5.4 °C so that every possible event can be prepared for. This would make the average outside temperature 8.2°C. The refrigerator used shall be an ideal refrigerator which will be the most efficient and enable the calculation of the lowest amount of work needed to cool Alaska.

Results

Firstly we used the known temperatures within and outside the cube to calculate the coefficient of performance (COP) for the refrigerator using equation (1) [3],

$$COP = \frac{T_{cold}}{T_{hot} - T_{cold}} \qquad (1)$$

where T_{cold} is equal to 2.8 °C and T_{hot} is equal to 8.2 °C giving a maximum coefficient of performance of 0.52.

The energy change associated with cooling Alaska is given by the heat equation (2) [4] where Q_c is the heat energy needed to be lost, M is the mass in the cuboid, c is the specific heat capacity and ΔT is the temperature change.

$$Q_c = M \times c \times \Delta T \tag{2}$$

To utilise this equation the mass contained within the cube had to be calculated. We are assuming that the volume of the cube is filled with air with the density and pressure of dry air at sea level which has a density of 1.25 kgm^{-3} [5] meaning using the volume of the cuboid via $m = \rho \times V$ there is a mass of 1.1×10^{17} kg.

The specific heat capacity of dry air is equal to 1005 $\text{Jkg}^{-1}\text{K}{-1}$ [6] and this can be used with the mass and temperature change in equation (2). This gives a heat energy to be lost of 5.6×10^{20} J. This is then used in equation (3) the coefficient of performance equation. [4]

$$W = \frac{Q_c}{COP} \tag{3}$$

The amount of work needed to be done to cool down Alaska in 2100 AD to temperatures in 2019 AD is 1.1×10^{21} J.

Discussion

The value calculated is only an approximation of how much energy it would take to cool down Alaska. It assumes many things that are false, such as that everything within the cube would be dry air, which is not the case and would increase the work needed. We assumed that the cube was a perfect insulator despite this being impossible as the atmosphere would heat the cube, which will heat inside. This would cause the refrigerator to use more energy.

The amount of energy needed to cool Alaska down to 2.8 °C is very large and makes the project unfeasible. 1.1×10^{21} J of work is a significant amount of energy that could not be supplied easily. This energy would most likely be supplied from the burning of fossil fuels, as would the energy used in the manufacture and construction of the cube. This would further contribute to global warming making the initial problem worse.

Conclusion

Trying to stop global warming in Alaska by building an insulating cube over the top of it is not to be advised as it is ineffective and requires significant amounts of energy. The process would further damage the environment and put more carbon CO_2 into the atmosphere causing increased global warming.

References

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