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P6_4 Heating of the Earth's Atmosphere and Oceans as a Direct Result of Energy Production

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Abstract
We examine the effect of waste heat generated in the energy production industry and how this increases global temperature. We compare this to the effects of greenhouse gasses, and also to the total radiant intensity of the Sun. We have found that this waste heat generated produces a temperature change that is two orders of magnitude less than that gained from the Sun, and therefore has been an insignificant increase since the beginning of industrial scale power generation. We forecast that even by the year 2050 the waste heat generated by power production will be $0.1mKyr^{-1}$, two orders of magnitude lower than the heat trapped as a result of greenhouse gas related global warming, and is also insignificant.

Introduction
This paper aims to quantify the waste heat produced from global power generation and its effect on global temperature, comparing this to the effect of greenhouse gases. We make a number of assumptions within this paper, such as that the UK is typical in the ratios of nuclear, fossil and renewable energy sources and that all waste power produced is converted directly to heat which escapes into the atmosphere.

Calculations
It is estimated that on average, power generation is approximately 31% efficient [1], extrapolating from total annual world energy demand of $1.91 \cdot 10^{13} kWh$ [1], we get a figure of $6.17 \cdot 10^{13} kWh$ for total energy production. This gives a total wasted energy of $4.26 \cdot 10^{13} kWh$. If we assume all this waste energy is released directly into the atmosphere and oceans, we calculate the effect on the temperature of the planet that this energy production has.

The total mass of the atmosphere is estimated to be $5.30 \cdot 10^{18} kg$ [2], with a specific heat capacity of $1.01 Jg^{-1}K^{-1}$ [3], providing a total heat capacity of $5.35 \cdot 10^{18} kJK^{-1}$. The total mass of the oceans is $1.37 \cdot 10^{21} kg$ [4] and the specific heat capacity of ocean water is $3.99 kJg^{-1}K^{-1}$ [5], giving a total heat capacity of $2.12 kJK^{-1}$.

Using the formula $Q = mc\Delta T$ where Q is the total energy added to the system, m is the total mass of the material, c is the specific heat capacity of the material, and ΔT is the change in temperature. Substituting in values for the specific heat capacities and masses of the oceans and atmosphere, assuming the oceans and atmosphere are in thermal equilibrium, as such the temperature increase will be equal across them, yields the formula

$$\Delta T = Q/(m_o c_o + m_a c_a), \quad (1)$$

where m_o is the total mass of the ocean water, c_o is the specific heat capacity of the ocean water, c_a is the specific heat capacity of the atmosphere and m_a is the total mass of the atmosphere. This provides a temperature rise of $2.79 \cdot 10^{-8} Kdy^{-1}$, or $1.02 \cdot 10^{-5} Kyr^{-1}$. However this is likely to be slightly higher than the true figure as some of this energy will be used in heating homes or will quickly escape into space without heating the planet. For comparison, the Sun provides $9.40 \cdot 10^{16} W$ [6], or $8.12 \cdot 10^{21} Jdy^{-1}$, equivalent to a temperature rise of $1.48 \cdot 10^{-6} Kdy^{-1}$.

Discussion
Using data on world energy consumption since 1820 [7], and assuming energy efficiency has always been 31%, it is possible to construct a graph of the global temperature rise over a period which encompasses the Industrial Revolution, as shown in Figure 1.

The exponential increase of the temperature change shown in Figure 1, doubling approximately every thirty years, suggests at current rates of fuel demand and power generation efficiency by 2050 the heat

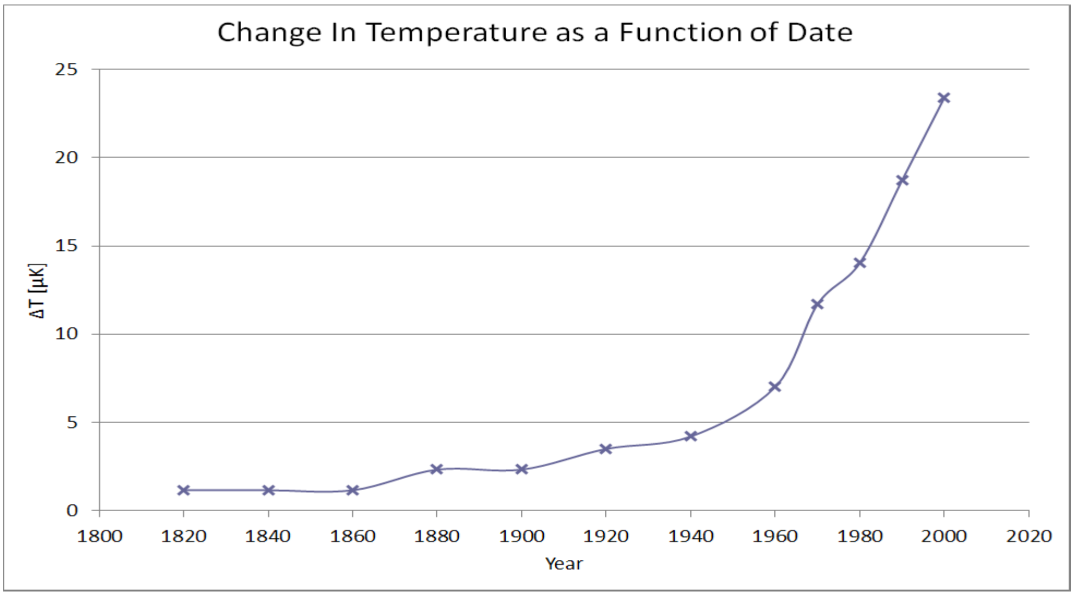

Fig. 1: Computed results for temperature change since 1820

generated by power production is likely to approach $0.1mKyr^{-1}$. Although a more accurate graph may consist of a shallower slope to take into account efficiency improvements, with a higher percentage of waste heat being produced further back in time, this is unlikely to drastically influence the final shape of the graph and is not significant enough to affect the conclusion of the paper. The temperature rise predicted by 2050 of $0.1mKyr^{-1}$ is still two orders of magnitude smaller than the $0.01 - 0.02K$ temperature rise predicted by the Intergovernmental Panel on Climate Change [8] as a result of global warming. Therefore although waste heat production in power generation may have a measurable effect on global temperatures it is far less significant than the production of greenhouse gases, also produced as a by-product of electricity generation, in current global warming trends.

Conclusion

The heat absorbed by the oceans is likely to be a drastic over-estimate of the true value as the deep ocean currents move on a 1000 year cycle [9] and as such the lower layers may be effectively shielded from the heat increases described above. As an extension of this paper, it may be possible to recalculate the temperature rise using a shallower ocean layer. Although several approximations have been made for the simplicity of this paper, such as assuming an even distribution of temperature rise between the oceans and atmosphere and neglecting feedback effects which are beyond the scope of this paper, these are not significant enough to affect our conclusions. Although the temperature rise from power generation is measurable, it is unlikely to be significant due to several over-powering factors such as background noise and fluctuations and by global warming gases, which have an effect approximately one hundred times greater than direct heat production.

References

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