Donald E. Watenpaugh, PhD
1 Feb. 2020

Does heat from friction contribute to global warming?

Abstract: Earth's atmospheric temperature is increasing faster than climate change models predict. Heat from anthropogenic friction may explain this observation. Conservation of energy dictates that energy used to propel and stop vehicles eventually becomes heat. This previously unacknowledged heat emanates in part from vehicular boundary layer aerodynamics and braking systems. The number of aircraft and ground-based vehicles in use suggests anthropogenic frictional heat may be a significant contributor to global warming. These observations support much wider use of regenerative braking systems.

Key words: global climate change, thermodynamics, conservation of energy, brakes, aircraft, vehicles, anthropogenic heat, regenerative brakes

Earth's atmosphere is heating up faster than predicted by climate change models (e. g. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GL082062). Those models assume that greenhouse gas accumulation is the sole cause of global warming (https://aiche.onlinelibrary.wiley.com/doi/full/10.1002/ep.13041; https://publisher.uthm.edu.my/ojs/index.php/ijie/article/view/2269/1684).

The discrepancy between predictions and reality raises the question: are greenhouse gases truly the singular cause of global warming? There may be at least one additional, important, and as yet unrecognized contributing factor: the first law of thermodynamics, which dictates conservation of energy. Or, in more simplistic terms, heat from anthropogenic friction.

Obviously, combustion of fossil fuels creates heat, but climate change researchers consider this inconsequential relative to the greenhouse effect (https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2015GL063514). The role of heat from friction hasn't previously been considered. The first law stipulates that energy used to propel and stop vehicles eventually becomes thermal energy, or heat.

At least two sources of anthropogenic frictional heat may be significant contributors to climate change. One is aircraft. Airliners cruise pan-globally at high

subsonic speeds. There are roughly 10,000+ planes airborne at any given time. Commercial jet aircraft cruise in the lower stratosphere. How much does frictional heat add to heat from jet fuel combustion? Does direct heating of the atmosphere at this level somehow accentuate the greenhouse effect or otherwise magnify tropospheric heating? These are speculations, but the fact remains that thermal effects of aircraft haven't been excluded as causative factors to global warming.

An even more significant source of frictional heat may be brakes. Brakes use friction to decelerate and stop wheeled vehicles: bikes, cars, trucks, trains, even landing aircraft. In doing so, the vehicle's kinetic energy is converted to heat. Depending on frequency and duration of braking, brake discs, drums, and nearby components reach temperatures of 200 – 600°C. A single automobile front brake assembly weighs ~ 15 kg. Braking a car from a moderate speed to a complete stop generates several MJ of heat. There are well over a billion cars on Earth, and most are driven in urban areas where braking is frequent. Without doing the detailed global calculations, it becomes clear that automobile brakes release vast amounts of heat into the atmosphere.

Consider stopping a 10,000 metric ton train travelling at 20 m / s. Remember conservation of energy: the moving train's kinetic energy equals 2000 MJ. All of this converts to heat during stopping. Again, since most vehicular braking occurs in large urban areas, vehicular frictional heat concentrates in those areas.

This preliminary analysis of frictional heat and planetary warming calls for a more detailed and quantitative approach. Findings may support more attention to boundary layer physics and streamlining of vehicles, especially aircraft.

However, even without further investigation, the above observations support much wider use of regenerative braking systems (https://www.nature.com/articles/129864a0). Regenerative brakes convert a vehicle's kinetic energy into other more useful forms of energy than heat. That recovered energy can then be re-used to *propel* the vehicle, which reduces need for energy from fossil fuel combustion. Therefore, regenerative brakes conceivably decrease global warming by at least two mechanisms: reduced heat from brake friction *and* reduced greenhouse gas production.

Acknowledgements and Disclaimers
This work was supported by Studio Videnda LLC. We also thank the Watenpaugh and Del Cristo families for their patience and support, and Peter Norsk for preliminary review. This work was first submitted for publication in 1999. It was not accepted at that time, and it has not undergone formal peer-review since. A lay version of this white paper appears at https://www.studiovidenda.com/data-art#/rubbing-the-earth-the-wrong-way/.