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Sasha Klebnikov

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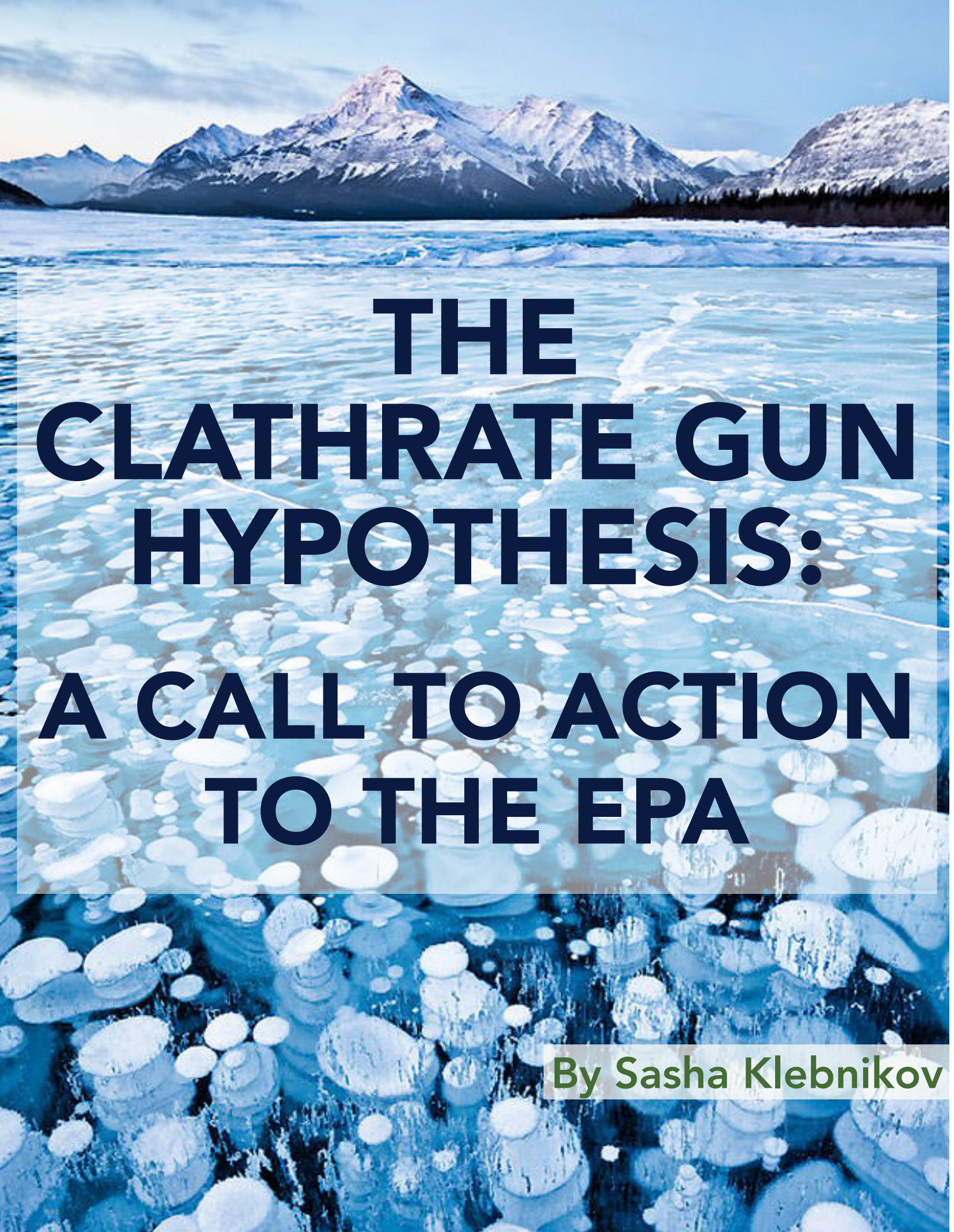


THE CLATHRATE GUN HYPOTHESIS:

A CALL TO ACTION TO THE EPA

By Sasha Klebnikov

"To declare national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality."

-NEPA Preamble, 1969

INTRODUCTION

The mandate of the Environmental Protection Agency (EPA) is "to protect human health and the environment." How and where this mandate has been applied has changed drastically over its 45 years of existence, but it is becoming increasingly clear that the issue of methane clathrates must now be accounted for.

Methane clathrates (also known as methane hydrates), are crystalline structures in which gaseous methane is trapped within water matrices. This occurs under high pressure, low temperature and high density. The global reserves of methane clathrates are enormous, with studies suggesting there is equivalent carbon (in terms of warming potential or potential energy) compared to between half and three times the reserves of all other fossil fuels combined[1]. These reserves are most abundantly contained in either shallow continental shelves under the ocean and in Arctic permafrost.

What is worrying is that as local temperatures rise or reservoir pressures decrease, methane clathrates degenerate into liquid water and gaseous methane. This methane then may bubble to the atmosphere, and then act as a potent greenhouse gas. As methane is released from an ice formation, the local hydrostatic pressure in the formation decreases, causing more methane to be released--a positive feedback loop. As such, massive volumes of gas can rapidly enter the environment with only relatively minor changes in local conditions; a runaway reaction known as the 'Clathrate Gun' starts, causing drastic global temperature rise.
Due to the urgent risk of substantial climate change, specifically where scenarios of warming exceed 6°F,[2] the burden of preventive action falls on the EPA, private organizations and the US Executive Office. Under the framework of the Clean Air Act of 1970, the National Environmental Policy Act of 1969, and the rulings of Massachusetts vs EPA (2005), it appears that the EPA has sufficient authority to increase regulations on methane emissions, but firm emission limits are driven by economic and political concerns, not environmental considerations. Indeed, the concrete and severe threat of a 'Clathrate Gun' will likely be enough to enable the EPA to begin a new set of more wide-reaching, national, emissions regulations, without relying on the Clean Air Act for authority.

METHANE CLATHRATES

Methane clathrates are solid clathrate compounds in which large amounts of methane (CH_4) are trapped within an H_2O crystalline structure, similar in shape to ice. Methane clathrates form in the Gas Hydrate Stability Zone (GHSZ), a region bounded by having a high pressure and a low temperature (Figure 1), which is typically above 1500m. Clathrates can occur both under the ocean, near coastlines and in permafrost. While many studies have examined the effects of oceanic clathrate formations on ocean acidification and the threat of underwater clathrate releases, these situations provide a less urgent threat than

The NGO Resource Centre Climate Change Working Group, "What is the Climate Change Working Group?" Accessed Oct. 25, 2015, VUFO - NGO Resource Centre. http://www.ngocentre.org.vn/web-fm_send/849
The NGO Resource Centre Climate Change Working Group, "What is the Climate Change Working Group?" p. 2.
Ibid.
Ibid.

Arctic formation degradation; such oceanic effects occur over decades, while Arctic clathrate releases occur on a timescale of just years.

Arctic methane clathrates are typically bound within large ice structures. Due to the low temperature of permafrost, Arctic clathrate formations can exist very near the surface. Indeed there are several productive natural gas reservoirs in Siberia, such as the Messoyakha field, that are believed to be slowly decaying methane clathrate formations.

Most Arctic clathrate formations are so called 'secondary deposits': the formation cycles between pure hydrate and a water-hydrate-gas mixture. Due to the ~500m thick permafrost cap, there are effectively no escape vectors for the gas, so the formations stay sealed for millions of years. The concern is that as global temperatures rise and short term temperature anomalies become more drastic[3], new escape vectors in the permafrost will form, allowing the release of gas.

There is a clear record that this has happened before when a reservoir slump in South Carolina 14,000 years ago discharged enough methane to increase atmospheric levels by 4%[4] changing the entire atmosphere in less than a week. There is fear that this phenomena may rapidly occur at multiple nearby reservoirs, setting off a chain reaction (the proverbial Clathrate Gun).

METHANE IN THE ATMOSPHERE

Over a span of 100 years, a single molecule of methane has equal warming potential as 28 units of CO2. However, for shorter time periods it is much higher, with a Global Warming Potential (GWP) of 84[5], in which a single ton of methane can cause the same global temperature rise over the next twenty years as 84 tons of CO2.

Methane require hydroxyl radicals (OH ions) to be broken down. When high concentrations are released too quickly, demand for OH ions exceeds supply[6,7,8]. The conditions in the

Arctic will likely prevent full degradation of methane releases, increasing the impact of large-scale methane discharge. Taken together this suggests an ominous feedback loop.

An even more important metric than Global Warming Potential is Local Warming Potential (LWP). It typically takes ~6 months for gases to fully disperse from their emission site, but for the Arctic, the lack of the Jet Stream slows migration. It is conservative to expect 20% of any Arctic methane release to remain in place after five years. In this scenario (Figure 2), a methane clathrate release would have the same warming potency (LWP) as a CO2 release 1000 times its size emitted elsewhere.[9,10]

Thus, the decay of any single methane clathrate formation may cause drastic local warming and temperature aberrations, setting off runaway warming scenario known as the Clathrate Gun. Lawrence Berkeley National Lab[11] named methane clathrate destabilization as one of the 'Four Horsemen of the Apocalypse', noting massively elevated methane concentrations during the thermal maximum between the Paleocene and Eocene epochs, some 55 million years ago, causing temperatures between 5□ and 8□ higher than today.[12]

Despite apocalyptic predictions, the science is not conclusively settled. Estimates for Arctic emissions vary from 6 to 50 times[13] current atmospheric methane levels. The most recent

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
Shindell, D.T., G. Faluvegi, D.M. Koch, G.A. Schmidt, N. Unger, and S.E. Bauer, 2009: Improved attribution of climate forcing to emissions. Science, 326, 716-718, doi:10.1126/science.1174760.
Taraborelli, D et al. "Hydroxyl radical buffered by isoprene oxidation over tropical forests" Nature Geoscience 5, 190-193 (2012). doi:10.1038/ngeo1405
Khalil, M.A.K., Rasmussen, R.A., "Causes of increasing atmospheric methane: Depletion of hydroxyl radicals and the rise of emissions", Atmospheric Environment 19, 3, 397-407, (1985)

studies suggest it is reasonable to expect a widespread methane clathrate degradation event would push atmospheric methane levels to 12 times of our current value.[14] However, as methane clathrates have been trapped for millions of years, it is also not clear whether the threat will actually come in play on the time-frames we are considering. Without witnessing an actual clathrate formation slump in real time, the science remains ambiguous.

BASIS FOR REGULATION

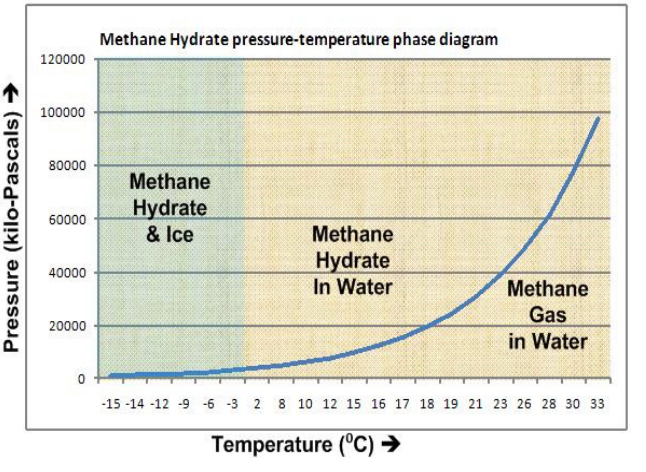
With this data in mind, we must address the question of how to reign in the fourth Horseman. This is not a local, state, or even a national issue, but an apocalyptic global threat that must be understood, quantified and prevented. Abrupt climate change due to a Clathrate 'Gun' is similar to Marine Icesheet Instability (MII) or an albedo driven positive feedback loop in the Arctic/Antarctic; an existential threat to humanity.The question becomes whether the threat is imminent enough to warrant legal action.

One cannot regulate methane clathrates under a simple toxicity basis - the EPA does not consider methane one of its 187 regulated Hazardous Air Pollutants, as it has minimal human health impacts. At atmospheric concentrations, methane is not combustible, nor will it directly cause substantial environmental harm, and is subject to EPA regulation only in regards to its role as a potent greenhouse gas.

The EPA's basis to regulate Greenhouse Gases (GHGs) was a highly contentious argument, only settled after the Massachusetts vs EPA Supreme Court Case of 2005. Massachusetts sued the EPA to force it to regulate Carbon Dioxide and other GHGs as pollutants, while the EPA argued that scientific ambiguity about the human threat of warming was sufficient grounds to not regulate GHGs. The argument presented by Massachusetts was that the toxicity of CO2 is not just based on its immediate health effects on humans, but also the implications of warming.

The court ruled that the EPA is mandated to regulate, control and reduce greenhouse gases under sections 202 and 111(d) of the Clean Air Act. The original language of the Clean Air Act of 1970 was specifically broadly written, defining an 'Air Pollutant' as even "a precursor to the formation of any air pollutant".[15] It is clear that both CO2 and CH4 fall within this definition, and since 2005, this Supreme Court decision has been reaffirmed on three subsequent occasions.[16]

Thus it is clear there are legal grounds for regulating typical methane emissions under the Clean Air Act (CAA). However,currently these regulations derive from the Vehicle Performance Standards, which mandate more fuel efficient cars, and Stationary Emission Sources (Power Plants, factories, etc.) sections of the CAA, limiting the EPA's ability to directly prevent methane emission from methane clathrates, as the emissions are not directly caused by human agency.



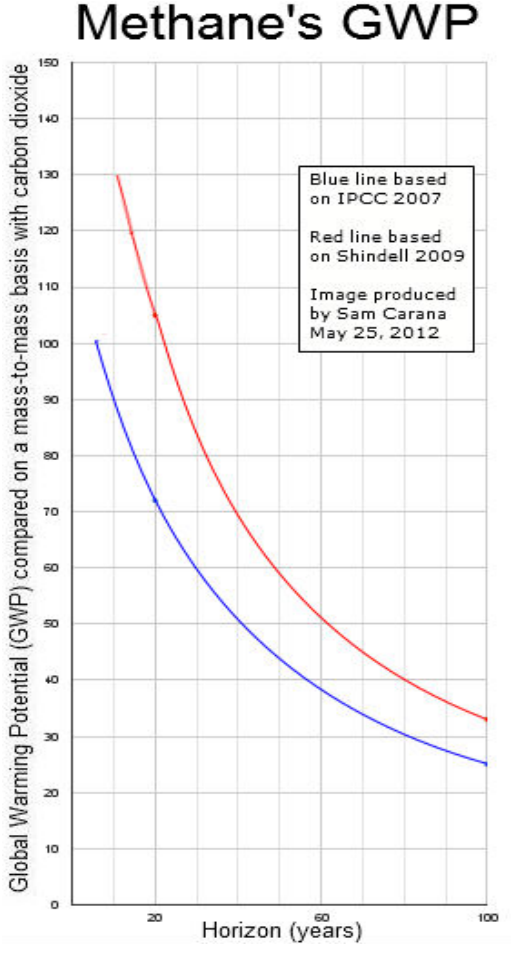
If, however, one argues that human emissions of GHGs are a direct cause of future methane emissions from clathrate formations, there is a strong argument for the EPA to increase limits on GHG emissions, setting more aggressive targets for maximum CO2 levels, atmospheric methane limits and global average temperature increase (such as keeping global temperatures below 1.5-2?, set in the 2015 Paris talks). New limits must be based on distinct methane clathrate degradation temperature limits, not the current vacuous goals suggested by the IPCC or an EPA Scientific Advisory Board.

Fundamentally, the legal basis for the 'Clean

Goddard Institute for Space Studies, NASA, 'Interactions with Aerosols boost warming potential of some gases", Oct 29, 2009. Retrieved online at www.giss.nasa.gov/research/
Carana, S., "Methane Hydrates", April 1, 2013, Methane-Hydrates.blogspot.com
Cameron-Smith, P., Press, P., "IMPACTS: On the Threshold of Abrupt Climate Changes" Lawrence Berkeley Lab News, Sept 17,2008,
Rohl, U., Bralower, T.J., Norris, R.D., Wefer, G., "New chronology for the late paleocene thermal maximum and its environmental implications", Geology 28 (10): 927–930
Mrasek, Volker (17 April 2008). "A Storehouse of Greenhouse Gases Is Opening in Siberia". Spiegel International Online.

Power Plan' (2015) sets goals for electricity generating stations to reduce emissions, allowing for cuts in other sectors to fulfill the same goal. Through a 'cooperative federalism' model, the EPA allows states flexibility in the allocation of those reductions either from the generating stations themselves or other means. The EPA sets a 'minimum environmental standard' realistically determined by best available technology; however, its implementation can come from any source, allowing the EPA to influence (but not require) emissions reductions from all sectors of the US economy.

Is the Clean Power Plan limited in setting the severity of its reductions? There is no formal legal limitation that sets US targets to a 32% decrease in CO2 by 2030[17]. These limits were set for political and technical reasons and there are few obstacles to making them more stringent. The only requirement is to ensure that any emission reduction targets do not cause undue harm to citizens, financial or otherwise.



Redefining an increased risk for GHG emissions incentivizes, but does not empower, the EPA to take more drastic action. There is existing legal framework sufficient for further action to reduce US GHG emissions; the level is driven by MACT (Maximum Available Control Technologies) standards and the Obama Administration's priorities. Ramping up standards would be politically unpopular, but feasible.

Legally, harm from GHG emissions is considered roughly linear. This relationship drives the current standards for emissions reductions, in which the EPA/Administration balances a desire for lower environmental impact with economic burden. As global temperatures rise, sea levels and subsequent erosion rise steadily and storms increase in severity and frequency as the atmosphere becomes more energetic. However, the current scientific consensus does not suggest a "trigger" or sudden spike.

There may be triggers, such as changes in ocean currents or macroscopic weather patterns, that have not been thoroughly quantified yet and remain hard to predict. However, methane clathrate emissions are different. Their runaway nature, due to intense, contained, local heating and spiralling emissions triggered by new openings of specific gas escape vectors in the permafrost, means that it is possible to quantify exactly at what point a formation will begin to decay. This is obviously no trivial task, but far more realistic when compared to predictions such as hurricane intensity forecasts.

By defining a quantifiable level above which emissions would cause catastrophic damage could empower new action. If confident that a clathrate formation would denature above a certain point, then the EPA could gain additional power under NEPA to regulate far more than it currently does -- negating the inevitable lawsuits.

This means more wide reaching regulations, potentially affecting the domestic, agriculture,

transport and power industries. The emerging scientific consensus on the 'Clathrate Gun' will need to be considered in many Environmental Impact Statements. Once it is declared an immediate environmental and human health risk, the EPA would need to either enact new regulations, prove their existing actions are sufficient, or expand after litigation in a similar manner to Massachusetts vs EPA, 2005.

CONCLUSION

It is critical that we very clearly understand key thresholds for methane clathrate emissions. EPA mission creep comes primarily from identifying a novel type of threat - direct, quantifiable imminent harm to humans from additional GHG emissions. Methane clathrates are a new type of harm, warranting a new Supreme Court case and new regulations. But to trigger this critical redefinition requires a clarity of scientific consensus far beyond what we have now. With only a few studies warning of the potentially catastrophic effects of methane clathrates, there is currently no basis for a drastic rewriting of our environmental policy. Given the threat to humanity from clathrates , many more studies must be initiated immediately.

The fundamental question is: will increasing scientific certainty in the existence of a 'Clathrate Gun' force the EPA to take more drastic action? No, as methane emitted from the permafrost is not directly caused by human actions, most existing regulations do not cover this. However, greater certainty and more concrete thresholds over initiation of the clathrate feedback loop could cause the EPA to undergo mission creep. Under the phrasing of NEPA, the EPA can be compelled to take a greater role in regulating and limiting GHG emissions in the US.

Overall, if the likelihood of the release of massive amounts of methane is well defined, the imminent harm to humans will be sufficient for the EPA to redefine its mission to prevent harm to citizens not just from actions emitted by our industries, but also from the atmospheric effects of otherwise benign air pollution. Such a redefinition of the role of the EPA is not to be taken lightly -- it is far more likely that a mandate for such drastic action will come first via executive order or congressional legislation. But should political gridlock prevent this, the EPA does have strong (if unconventional) legal grounding to take further drastic action.

Sasha Kleibnikov is a senior in the School of Engineering studying Mechanical Engineering and Applied Mechanics. He is the outgoing Editor in Chief of the Penn Sustainability Review, and is fanatical about all topics related to energy.