Agricultural operations, such as this feedlot at the Harris Ranch in California, are among the largest sources of human-caused methane emissions. *(Image credit: Getty Images)*

Removing methane from the atmosphere

Analyses lay out a blueprint for speeding development of methane removal technologies and modeling how the approach could improve human health and have an outsized effect on reducing future peak temperatures.

BY ROB JORDAN, STANFORD WOODS INSTITUTE FOR THE ENVIRONMENT

STANFORD EARTH MATTERS: CLIMATE CHANGE, HUMAN DIMENSIONS AND SUSTAINABILITY

September 26, 2021

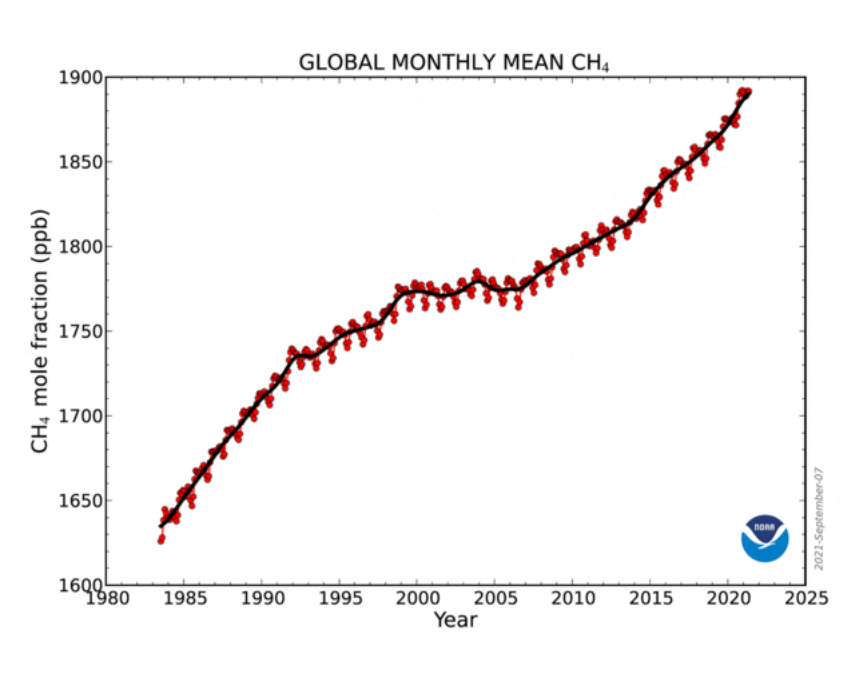
Earlier this month, President Biden urged other countries to join the U.S. and European Union in a commitment to slashing methane emissions. Two new Stanford-led studies could help pave the way by laying out a blueprint for coordinating research on methane removal technologies, and modeling how the approach could have an outsized effect on reducing future peak temperatures.

The analyses, published Sept. 27 in *Philosophical Transactions of the Royal Society A*, reveal that removing about three years-worth of human-caused emissions of the potent greenhouse gas would reduce global surface temperatures by approximately 0.21 degrees Celsius while reducing ozone levels enough to prevent roughly 50,000 premature deaths annually. The findings open the door to direct comparisons with carbon dioxide removal – an approach that has received significantly more research and investment – and could help shape national and international climate policy in the future.

"The time is ripe to invest in methane removal technologies," said **Rob Jackson**, lead author on the new research agenda **paper** and senior author on the modeling **study**. Jackson is the Michelle and Kevin Douglas Provostial Professor of Energy and Environment in Stanford's **School of Earth, Energy & Environmental Sciences**.

— The case for methane removal

The relative concentration of methane has grown more than twice as fast as that of carbon dioxide since the beginning of the Industrial Revolution. Removing methane from the atmosphere could reduce temperatures even faster than carbon dioxide removal alone because methane is 81 times more potent in terms of warming the climate over the first 20 years after its release, and about 27 times more potent over a century. Methane removal also improves air quality by decreasing the concentration of tropospheric ozone, exposure to which causes an estimated one million premature deaths annually worldwide due to respiratory illnesses.



Graph shows globally averaged, monthly mean atmospheric methane abundance determined from marine surface sites since 1983. *(Image credit: NOAA)*

Unlike carbon dioxide, the bulk of methane emissions are human-driven. Primary culprits include agricultural sources such as livestock, which emit methane in their breath and manure, and rice fields, which emit methane when flooded. Waste disposal and fossil fuel extraction also contribute substantial emissions. Natural sources of methane, including soil microbes in wetlands, account for the remaining 40 percent of global methane emissions. They further complicate the picture because some of them, such as thawing permafrost, are projected to increase as the planet warms.

While development of methane removal technologies will not be easy, the potential financial rewards are big. If market prices for carbon offsets rise to $100 or more per ton this century, as predicted by most relevant assessment models, each ton of methane removed from the atmosphere could then be worth more than $2,700.

> "Carbon dioxide removal has received billions of dollars of investments, with dozens of companies formed. We need similar commitments for methane removal.
>
> **ROB JACKSON**
> *MICHELLE AND KEVIN DOUGLAS PROVOSTIAL PROFESSOR*

— Envisioning methane removal's impacts

The modeling **study** uses a new model developed by the United Kingdom's national weather service (known as the UK Met Office) to examine methane removal's potential impacts while accounting for its shorter lifetime than carbon dioxide – a key factor because some of the methane removed would have disappeared anyway. The researchers created a set of scenarios by varying either the amount removed or the timing of removal to generalize their results over a wide range of realistic future emissions pathways.

Under a high emissions scenario, the analysis showed that a 40 percent reduction in global methane emissions by 2050 would lead to a temperature reduction of approximately 0.4 degrees Celsius by 2050. Under a low emissions scenario where temperature peaks during the 21st century, methane removal of the same magnitude could reduce the peak temperature by up to 1 degree Celsius.

"This new model allows us to better understand how methane removal alters warming on the global scale and air quality on the human scale," said modeling study lead author and research agenda coauthor **Sam Abernethy**, a PhD student in applied physics who works in Jackson's lab.

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> *PhD Student, Applied Physics*

— From research to development

The path to achieving these climate and air quality improvements remains unclear. To bring it into focus, the research agenda **paper** compares and contrasts aspects of carbon dioxide and methane removal, describes a range of technologies for methane removal and outlines a framework for coordinating and accelerating its scale-up. The framework would help facilitate more accurate analysis of methane removal factors ranging from location-specific simulations to potential interactions with other climate change mitigation approaches.

Methane is challenging to capture from air because its concentration is so low, but burgeoning technologies – such as a class of crystalline materials called **zeolites** capable of soaking up the gas – hold the promise of a solution, according to the researchers. They argue for increased research into these technologies' cost, efficiency, scaling and energy requirements, potential social barriers to deployment, co-benefits and possible negative by-products.

"Carbon dioxide removal has received billions of dollars of investments, with dozens of companies formed," said Jackson. "We need similar commitments for methane removal."

Jackson is also a senior fellow at the ***Stanford Woods Institute for the Environment*** *and the* ***Precourt Institute for Energy*** *and chairman of the Global Carbon Project. Coauthors of the research agenda paper include Josep Canadell of the Global Carbon Project;* ***Matteo Cargnello****, an assistant professor of chemical engineering at Stanford, Steven Davis and Chaopeng Hong of the University of California at Irvine; Sarah Féron, a postdoctoral fellow in Earth system science at Stanford at the time of the research; Sabine Fuss of Humboldt Universität in Germany;* ***Alexander Heyer*** *and Hannah Rhoda, PhD students in chemistry at Stanford; and* ***Edward Solomon****, the Monroe E. Spaght Professor of Humanities and Sciences at Stanford and professor of photon science at SLAC National Accelerator Laboratory; Maxwell Pisciotta and Jennifer Wilcox of the University of Pennsylvania; H. Damon Matthews of Concordia University in Montreal; Renaud de Richter of Ecole Nationale Supérieure de Chimie de Montpellier in France; Kirsten Zickfeld of Simon Fraser University in Canada. Coauthors of both papers include Fiona O'Connor and Chris Jones of the Met Office Hadley Centre.*

Both papers were funded by the Stanford Woods Institute for the Environment's ***Environmental Venture Projects program****, the Gordon and Betty Moore Foundation, the National Sciences and Engineering Research Council of Canada and the Joint UK BEIS/Defra Met Office Hadley Centre Climate Programme. The paper led by Sam Abernethy was also funded by the* ***Stanford Data Science Scholars Program*** *and the European Union's Horizon 2020 Crescendo Project.*

Learn more

JULY 2020

Global methane emissions soar to record high

The pandemic has tugged carbon emissions down, temporarily. But levels of the powerful heat-trapping gas methane continue to climb, dragging the world further away from a path that skirts the worst effects of global warming.

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APRIL 2021

The science behind decarbonization

A collection of research and insights from Stanford experts who are revealing the stakes of emission cuts, enabling better carbon accounting, predicting the consequences of future emission pathways and mapping out viable solutions.

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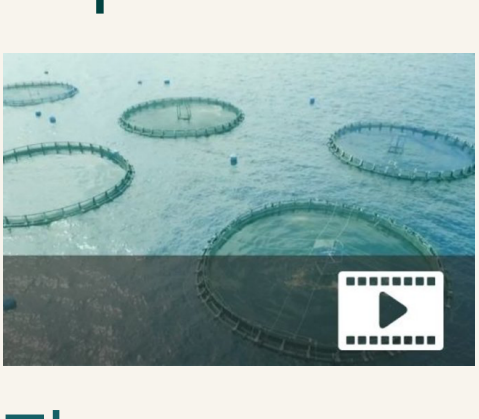

The economics of making fish feed with 'stranded' methane

Methane, a powerful greenhouse gas, can be captured and transformed into protein-rich feed for farmed fish – an increasingly important food sector. A new analysis shows how to make the approach more cost-effective than current fish feeds.

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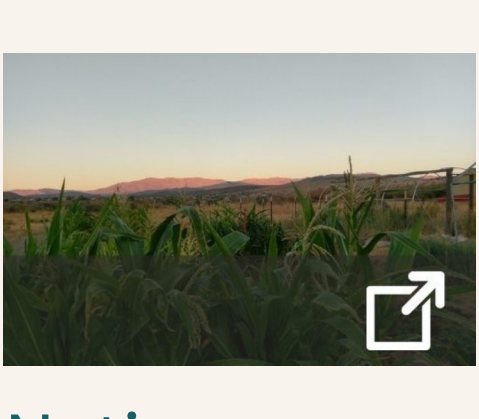

Native agriculture never went away. Now it is on the rise.

Despite persistent efforts by the U.S. government to eradicate Indigenous farming and ranching practices, they are regaining currency in an American West stressed by drought, diminishing resources and climate change. (Source: Bill Lane Center for the American West)

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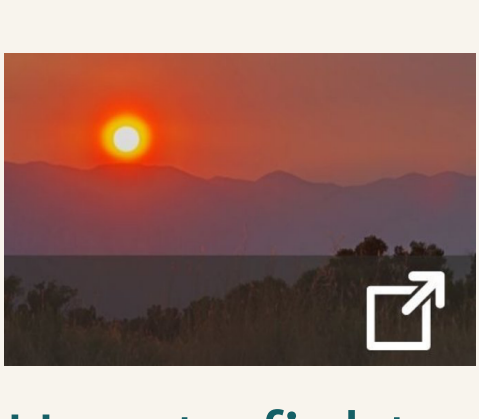

How to fight climate change

Environmental scientist Chris Field explains why taking on climate change will require that we continue to reduce emissions and adapt to the effects of increasing temperatures. (Source: Stanford Engineering)

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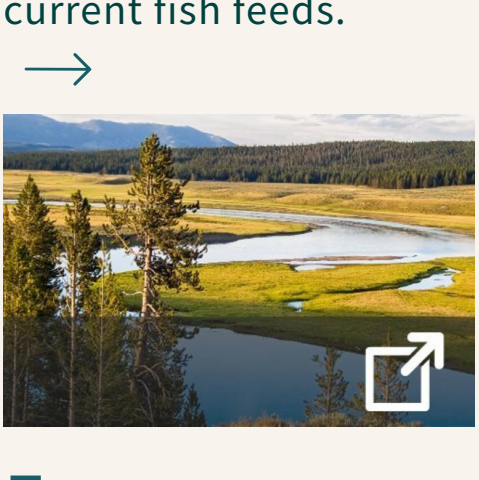

Four questions for Liz Hadly

The Stanford environmental biologist and global change specialist discusses recent flooding in Yellowstone National Park – and what it means for the future of the planet. (Source: Stanford News)

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