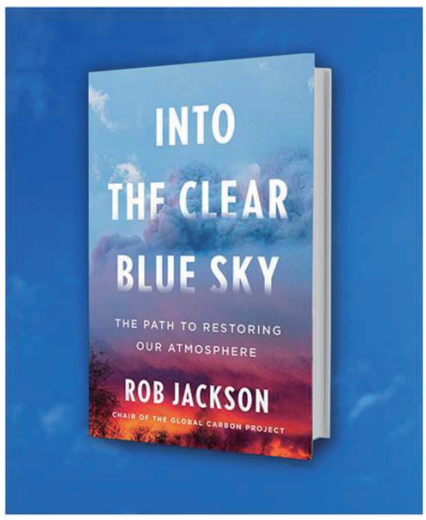
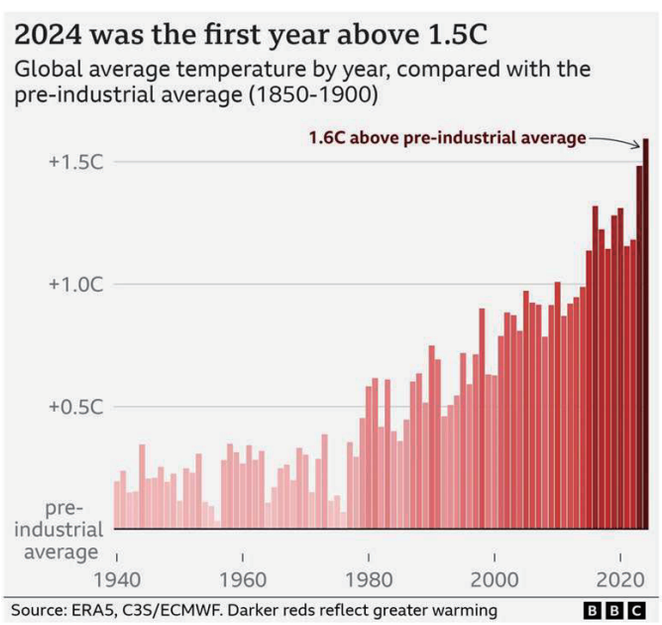
Restoring the Atmosphere: Hope, Health, and Humanity



rob.jackson@stanford.edu

Blue Planet Ceremony, Asahi Glass Foundation, Oct 2025

Climate change is here. 2023 was the warmest year (by far) until 2024…



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Climate change is here. 2023 was the warmest year on record until 2024 shattered that record as the first year the world reached more than 1.5 degrees C above preindustrial temperatures.

We're already paying for climate change. Billion-dollar weather disasters in the United States happen 8 times more often today than a few decades ago and already cost us $100 billion more per year (NOAA).

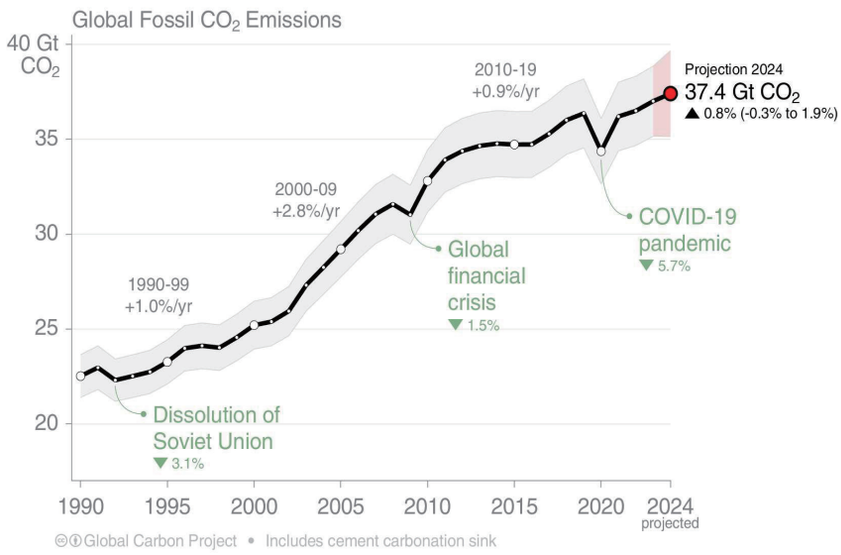
The 2017 Tubbs fire in Santa Rosa, CA, coupled an unusually wet winter with record heat.

The world's weather has gone weird, and we're already paying for climate change today. Billion-dollar weather disasters in the United States happen 8 times more often today than a few decades ago and cost Americans $100 billion more per year (NOAA).

An enormous "thank you" to my colleagues at the Global Carbon Project!
We track global emissions of CO_2, CH_4, N_2O and, more recently, H_2.

We at the Global Carbon Project track global emissions of the greenhouse gases carbon dioxide, methane, nitrous oxide and hydrogen. I wish to thank Prabir Patra and our Executive Director, Pep Canadell, both of whom are here today. This award really goes to you and to everyone in the Global Carbon Project who work tirelessly to measure and reduce greenhouse gas emissions worldwide. Thank you!

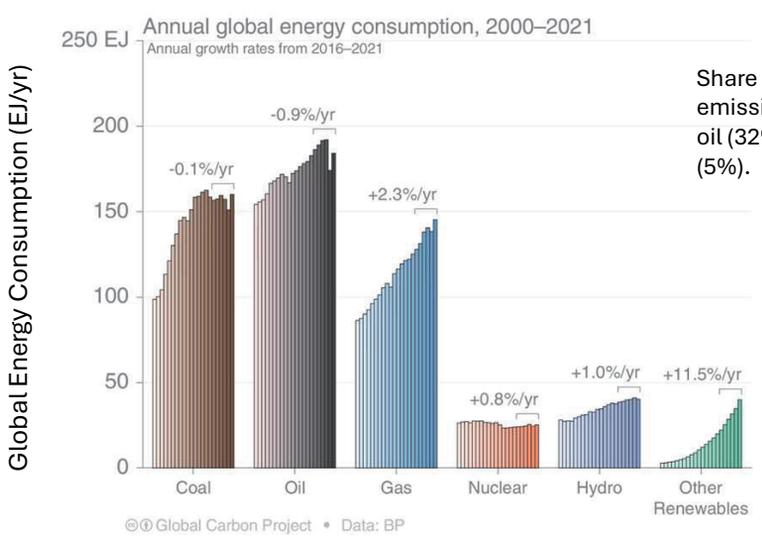
Fossil CO_2 emissions are still rising (37 billion tons, ~60% over 1990 levels).



Source: CDIAC; Friedlingstein et al 2024; Global Carbon Budget 2024

Fossil emissions of carbon dioxide, the world's dominant greenhouse gas, continue to rise. Now nearing 40 billion tons of pollution per year, emissions are 60% higher today than they were in 1990.

Why are carbon emissions still rising despite renewables growing at >10%/yr? Because global energy demand keeps increasing. No fossil fuel shows evidence of a decline in global use (yet).



Share of global fossil CO_2 emissions in 2024: coal (41%), oil (32%), gas (21%), cement (5%).

Jackson et al. 2022 Env Res Lett

Why are carbon emissions still rising despite solar power and other renewables growing at more than 10% per year? Because global energy demand keeps increasing. Not one fossil fuel shows evidence of a decline in global use yet.

Some industries are especially hard to decarbonize (steel, cement, and more.)

Some industries are especially hard to decarbonize, including steel, cement, and more. Their furnaces require extremely high temperatures of thousands of degrees.

They use coal in their furnaces

Steel manufacturing has usedcoal for more than a century.

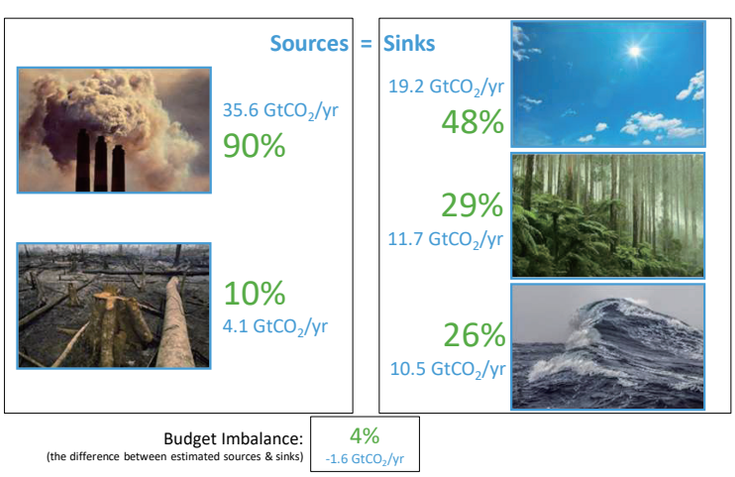
Green steel is coming but requires a price on carbon pollution.

However, the world's first steel made without coal or other fossil fuels is now being produced using clean hydropower and hydrogen generated onsite as a fuel to replace all coal used in making the steel.

GLOBAL CARBON PROJECT

Fate of anthropogenic fossil CO_2 emissions (2014–2023)

Land currently "absorbs" ~30% of global fossil CO_2 emissions; we need to protect forests, too!



Source: Friedlingstein et al 2024 Global Carbon Project 2024

Our forests and other lands globally currently absorb 30% of all carbon dioxide emissions. We need to protect them for this service and the many additional benefits they provide, including purifying oor water, cleaning our air, and protecting our soils.

Our forests provide many benefits and provide our best opportunities to store carbon. We're working to document the benefits of old-growth forests around the world.

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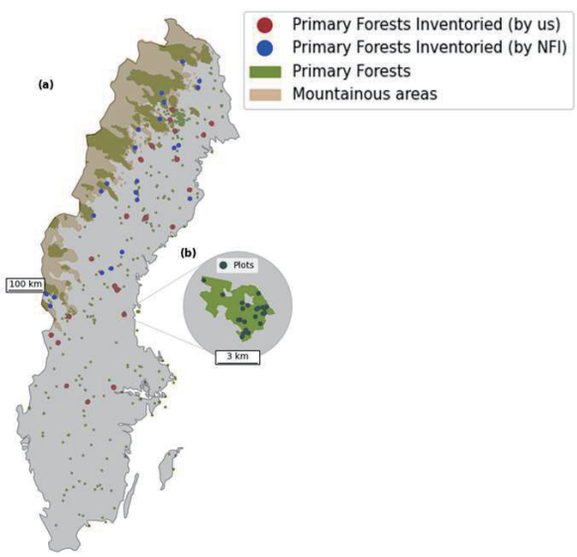
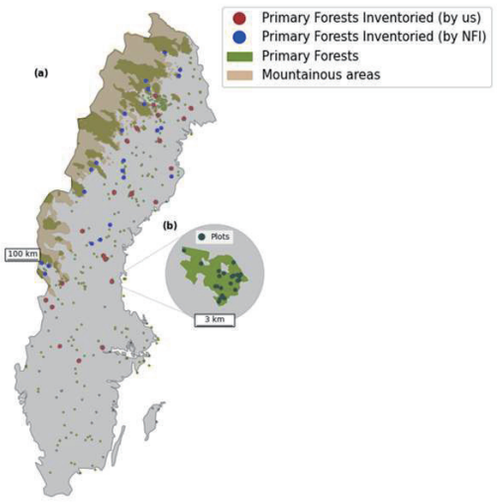
Step #1. Sample ~350 primary, old-growth forests in Sweden. Pair them with nearby or adjacent secondary forest plots



In Sweden, for instance, we're sampling dozens of old-growth forests and pairing them with industrial forest plots nearby to examine whether older forests store more carbon and host more diverse microbial communities.

Step #2. Estimate aboveground C biomass from national forest inventory plots, then sample soil carbon, roots, and mycorrhizal diversity in primary and secondary forests.



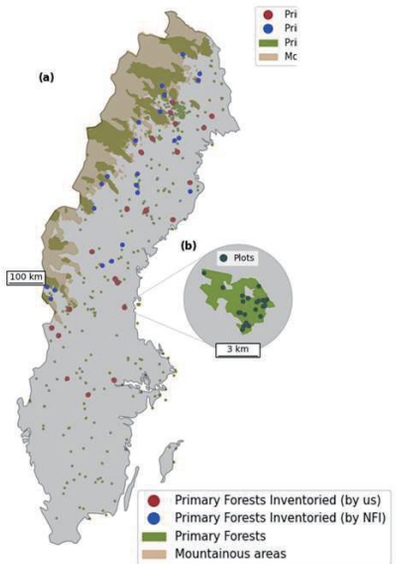
To assess changes belowground, we sampled soils, root, and the diversity of fungal symbionts of the trees.

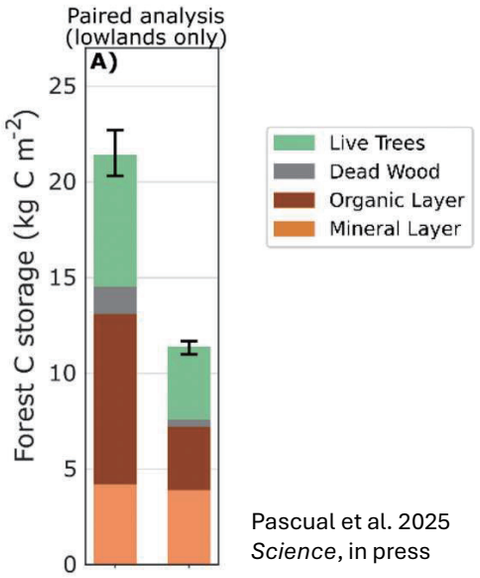
A healthy old-growth forest

Source: Phil Roberge, Stanford University

Here is an example of a healthy old-growth forest in Sweden.

Results: Old growth forests store twice as much organic carbon in soils (brown bars) and 72% more carbon overall. Why?





Pascual et al. 2025
Science, in press

We found that old-growth forests store twice as much organic carbon in soils (brown bars) and 72% more carbon overall. Why is so?

Hypothesis #1: Industrial planting, including disk trenching, mounding, and ploughing, reduces soil structure and health and accelerates decomposition.

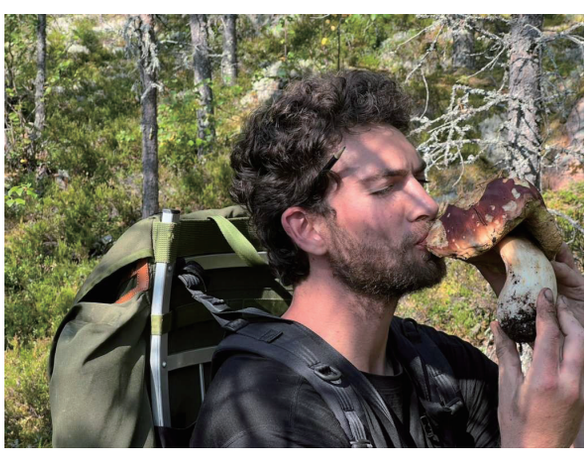
Hypothesis #1. Industrial forestry practices, including disk trenching, mounding, and ploughing, reduce soil structure and health and accelerate decomposition. Note the rows of rocks in the photo on the right where a blade has ripped open the soil.

A newly planted secondary forest. Industrial planting degrades soils

Source: Phil Roberge, Stanford University

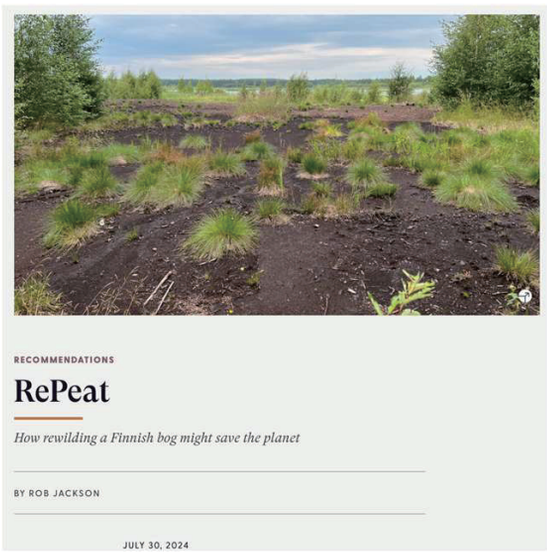
Here is what this practice looks like from above. These rows are where companies plant tree seedlings.

Hypothesis #2 Old growth forests have more abundant and diverse soil fungi that promote soil health and fertility. This community may increase tree growth and restoration success for secondary-forest restoration.



Hypothesis #2 Old growth forests have more abundant and diverse soil fungi that promote soil health and fertility. This healthier fungal community could increase tree growth and the success of industrial-forest restoration. We are transplanting the more diverse fungi found in old-growth forests into industrial forest plots to see if trees grow faster. We're assessing fungal diversity using molecular tools

Peatland restoration is another area of research, including methane emissions.



RECOMMENDATIONS

RePeat

How rewilding a Finnish bog might save the planet

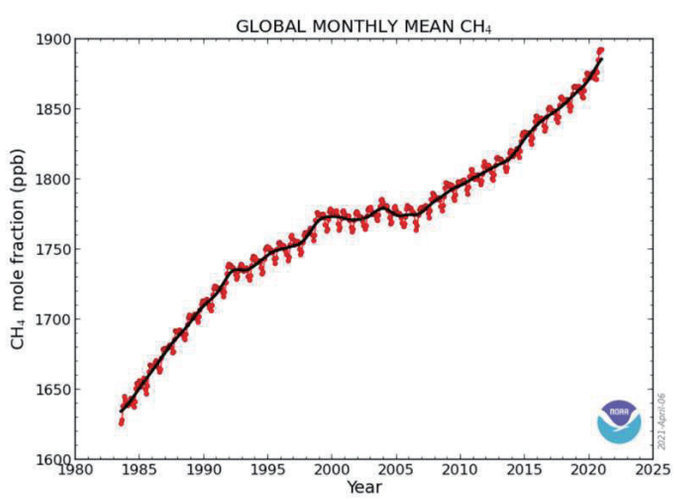
BY ROB JACKSON

JULY 30, 2024

Arctic permafrost and peatlands are especially vulnerable to warming. Carbon is already being lost to the atmosphere as permafrost thaws. Some of this material goes to the air as carbon dioxide. The rest is released by microbes as methane, a far more potent greenhouse gas than carbon dioxide and the focus of the rest of my presentation today.

Methane concentrations are rising even faster than CO_2

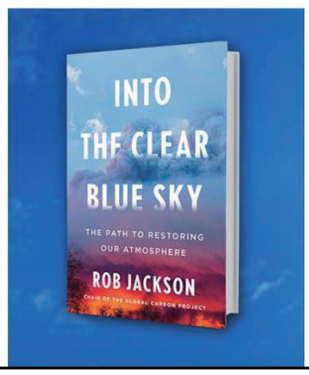
Methane is 85-times more potent than CO_2 after two decades. **It is the only GHG where mitigation can reduce peak temperatures over the next decade or two**.

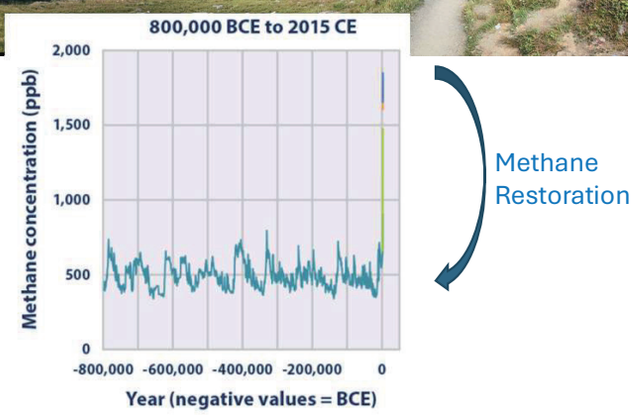


Lan et al. 2024, NOAA/GML

Methane concentrations are rising even faster than CO_2 . Methane is 85-times more potent than CO_2 after two decades and has a much shorter lifetime of only a decade. These attributes make methane the only GHG where mitigation today can reduce peak temperatures over the next decade or two—within the lifetime of anyone in this room.

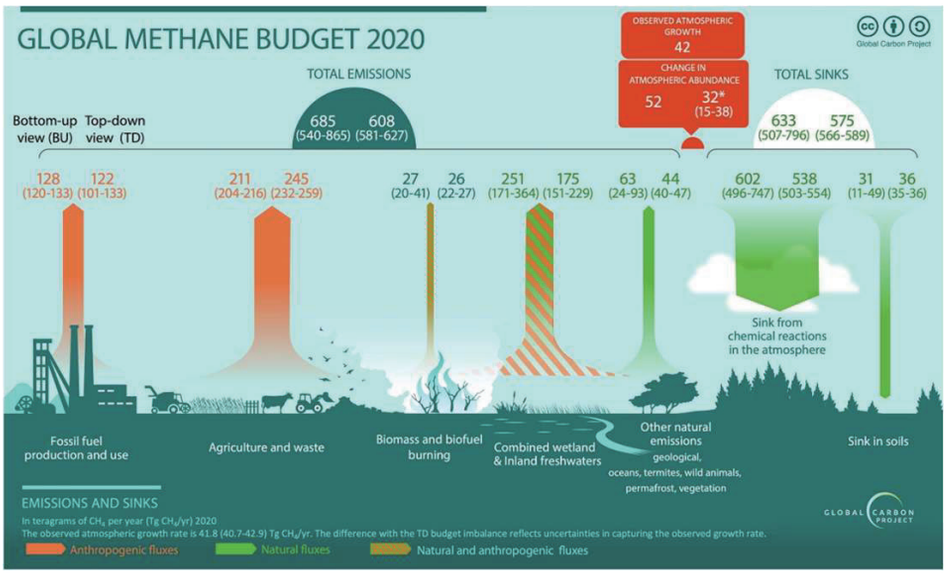
What would Restoration look like for methane and other GHGs in the atmosphere?





Methane is also the only greenhouse that could be restored to preindustrial concentrations within a few decades if we could end human-caused emissions. That's what I mean by "restoring the atmosphere" for methane or any other other greenhouse gas. Restoring methane would save half a degree C of warming and would save hundreds of thousands of lives by reducing surface ozone concentrations. Climate action helps the planet and makes us healthier.

Human activities release two-thirds of methane emissions. We need to reduce emissions from cows and energy (upward arrows to the left) *and* enhance sinks (arrows to the right). Wetlands are the largest natural source.



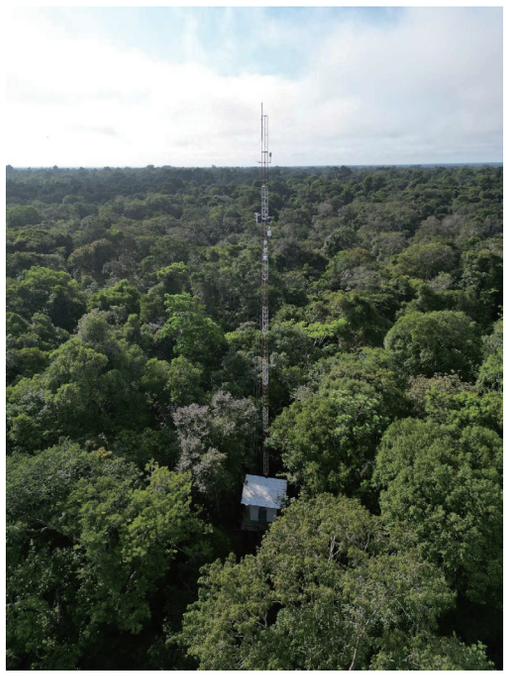
Saunois et al. 2025 ESSD; Jackson et al. 2024 Environ. Res. Lett.

Human activities release two-thirds of all methane emissions globally. We need to reduce emissions from cows and energy (upward arrows to the left) *and* enhance sinks (arrows to the right). Wetlands are the largest natural source of methane in the world.

Tropical wetlands are the largest natural source and their emissions are increasing.

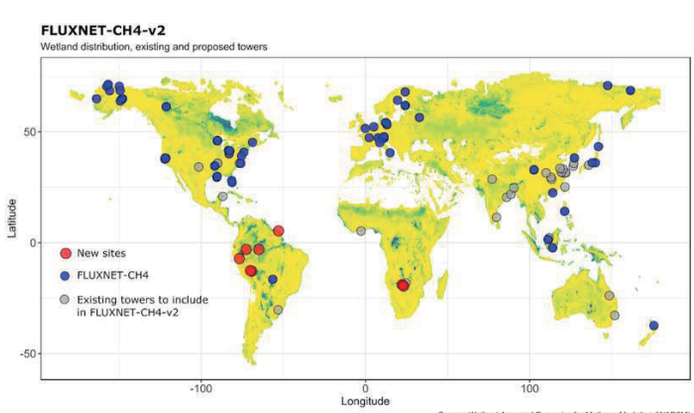
Tropical wetlands are the highest-methane-emitting ecosystem in the world. Unfortunately, methane emissions appear to be increasing in the Congo, Amazon, and other tropical wetlands as the Earth warms.

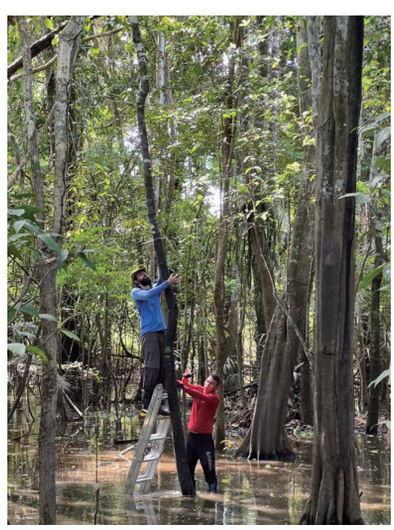
We measure methane emissions across the Amazon and elsewhere.



Even the most remote places on Earth are changing, including the Amazon. We measure methane emissions across the Amazon with partners in Peru, Brazil, French Guiana, and elsewhere. The photo on the right shows a monitoring tower that we just built at the Mamiraua Sustainable Development Reserve in Brazil. We're using it to measure methane and carbon dioxide emissions. I'm also lucky to see wildlife during my sampling trips, including giant river otters and this jaguar that I saw in March.

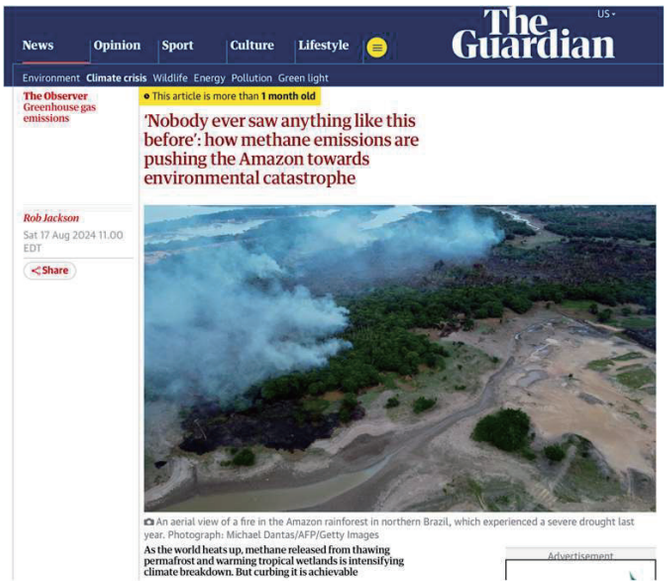
I thank our tropical collaborators (new measurement sites in red).





This map shows the places around the world where scientists are measuring methane fluxes using towers. The sites in red are the new sites we're building or instrumenting across the Amazon and into Africa. I wish to thank the many international colleagues in these countries helping to lead this work. Some of these friends and colleagues are shown along the bottom of this slide.

More than 20 million Amazon hectares burned in 2024, an area larger than CA. The river dropped to its lowest levels in a century. River dolphins cooked in water too hot to survive.



News Opinion Sport Culture Lifestyle

The Guardian US

Environment Climate crisis Wildlife Energy Pollution Green light

The Observer Greenhouse gas emissions

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'Nobody ever saw anything like this before': how methane emissions are pushing the Amazon towards environmental catastrophe

Rob Jackson

Sat 17 Aug 2024 11.00 EDT

Share

An aerial view of a fire in the Amazon rainforest in northern Brazil, which experienced a severe drought last year. Photograph: Michael Dantas/AFP/Getty Images

As the world heats up, methane released from thawing permafrost and warming tropical wetlands is intensifying climate breakdown. But curbing it is achievable

Advertisement

Climate change is already altering the Amazon. A drought in 2023 and 2024 saw the Amazon River drop to its lowest level in more than a century of measurements. River dolphins cooked in water too hot to survive. More than 20 million Amazon hectares burned in 2024 because of the drought, an area larger than my home state of California.

Reducing methane emissions from the **energy sector** is our best opportunity:

Closer to home, the best and cheapest places to cut methane emissions are in the energy sector. I work throughout this sector to slash methane leaks from oil and gas wells to natural gas pipelines under city streets to our homes and buildings. We fly airplanes and helicopters to find hotspots of emissions, drive cars to detect pipeline leaks in our cities, and sample methane emissions from gas appliances in our homes and buildings.

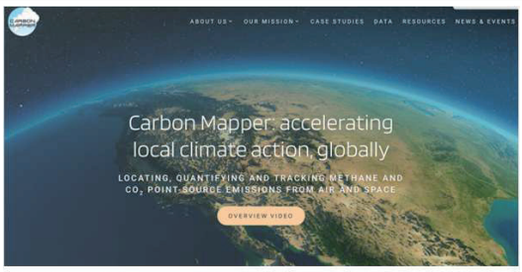
”Restaurant Inspections” to detect leaks at oil and gas facilities

Lyon et al. (2016) ES&T

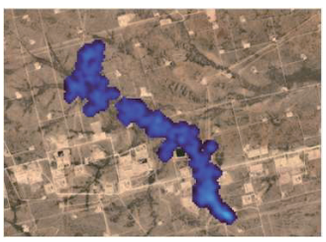
We fly helicopters to map methane leaks from oil and gas wells. The plume that you see in this video is invisible to the naked eye and can be detected only using a special infrared camera. Led by collaborator David Lyon, we flew ten thousand well pads randomly in seven oil and gas basins in the United States. I liken these studies to restaurant inspections because we arrive unannounced and measure which sites are leaking and who owns them. We found thousands of such leaks, one of every four locations we visited on average. We worked with companies and regulators to help fix these leaks.

GLOBAL CARBON PROJECT

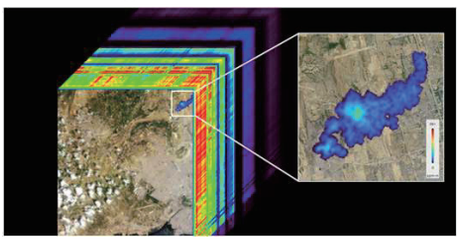
A better way : satellites can now map CH_4 "super-emitters" from space. Carbon Mapper released its first data last year.



Carbon Mapper Releases First Emissions Detections from the Tanager-1 Satellite



Oil & gas, Permian Basin, TX



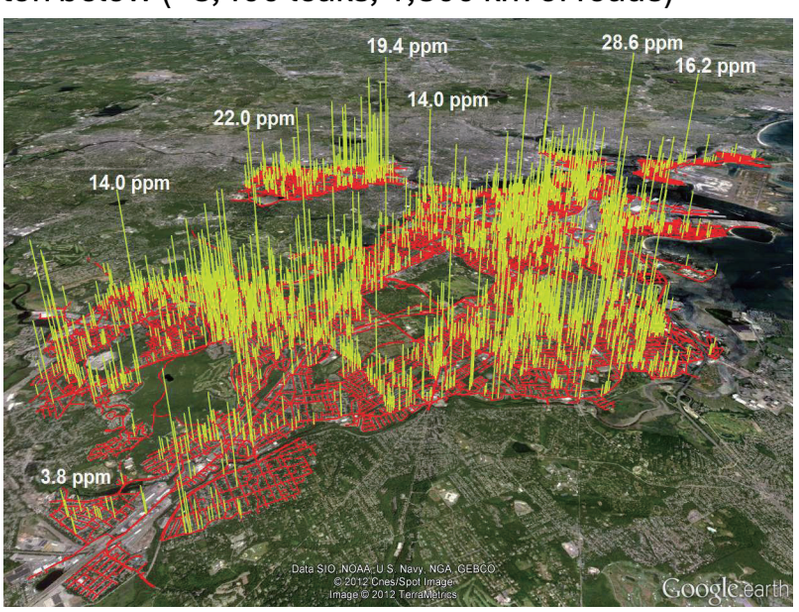
Landfill in Karachi, Pakistan (1200 kg CH4/hr)

There is a better way to find methane super-emitters today. We can map them from space. Here you see a methane plume from an oil and gas facility in Texas on the left and from a landfill in Pakistan on the right. Finding super-emitters is important because fewer than 1% of sites release more than half of emissions. And unlike flying an airplane, you don't need permission to use a satellite. You can look anywhere: Russia, China, and across the United States each day.

Downstream, we produced the first publicly available maps of gas pipeline leaks in cities: Boston below (~3,400 leaks; 1,300 km of roads)

Red = roads driven
Yellow = gas leaks

#1 predictor – miles of old cast-iron pipes



Phillips et al. 2013 *Env. Pollution*

Moving "downstream" from oil and gas fields to our cities, we produced the first publicly available maps of natural gas pipeline leaks in cities. My colleague Nathan Phillips of Boston University and I drove every block of Boston, Massachusetts—1,300 km— shown here in red for the roads driven. We mapped more than 3,300 leaks across the city illustrated as the golden spikes above. That's more than two leaks for every km of roads in Boston. The #1 predictor of a leak was old cast-iron piping.

Some Quick Responses:

Boston Mayor Tom Menino wrote a strongly worded letter to the Department of Public Utilities to increase pipeline scrutiny.

Congressman Ed Markey, MA 7th District wrote to PHMSA:
"This study shows that we need a plan to ensure leaks from aging natural gas pipelines in Boston and other cities and communities are repaired, so that we can conserve this important natural resource, protect the consumers from paying for gas that they don't even use, and prevent emissions of greenhouse gases into the environment."

July, 2014: MA passes a statewide pipeline safety bill to accelerate natural gas pipeline replacements and faster cost recovery for companies. The bill creates jobs, improves air quality, and reduces greenhouse gas emissions and the risk of explosions.

The city and state responded quickly to our map. Boston mayor Tom Menino wrote a strongly worded letter to the Department of Public Utilities to increase pipeline scrutiny. Then-congressman, now Senator, Ed Markey wrote a letter to the federal agency in charge of public safety: "This study shows that we need a plan to ensure leaks from aging natural gas pipelines in Boston and other cities and communities are repaired, so that we can conserve this important natural resource, protect the consumers from paying for gas that they don't even use, and prevent emissions of greenhouse gases into the environment." The next year, the state of Massachusetts passed a statewide pipeline safety bill to accelerate natural gas pipeline replacements and allow faster cost recovery for companies. The bill created jobs, improved air quality, and reduced greenhouse gas emissions and the risk of explosions. Safety more than climate was the factor driving this change.

Same outcome in Washington, D.C. “Project Pipes” began in 2014 after we mapped 6,000 leaks there. The response enhanced safety and reliability for 165,000 customers.

ENVIRONMENTAL Science & Technology

Article

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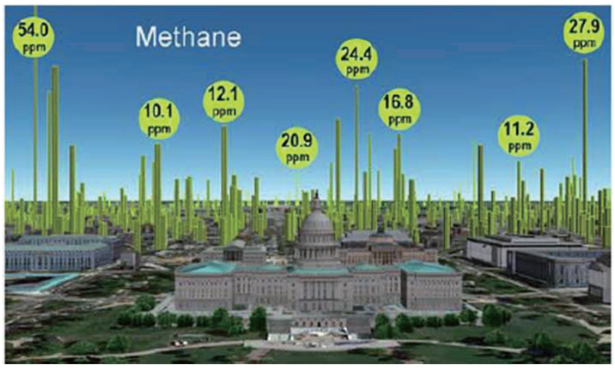
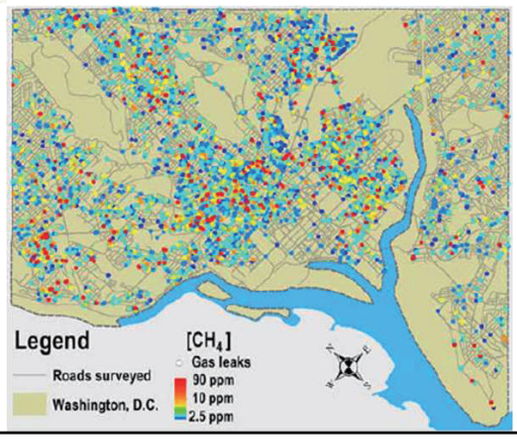
Natural Gas Pipeline Leaks Across Washington, DC

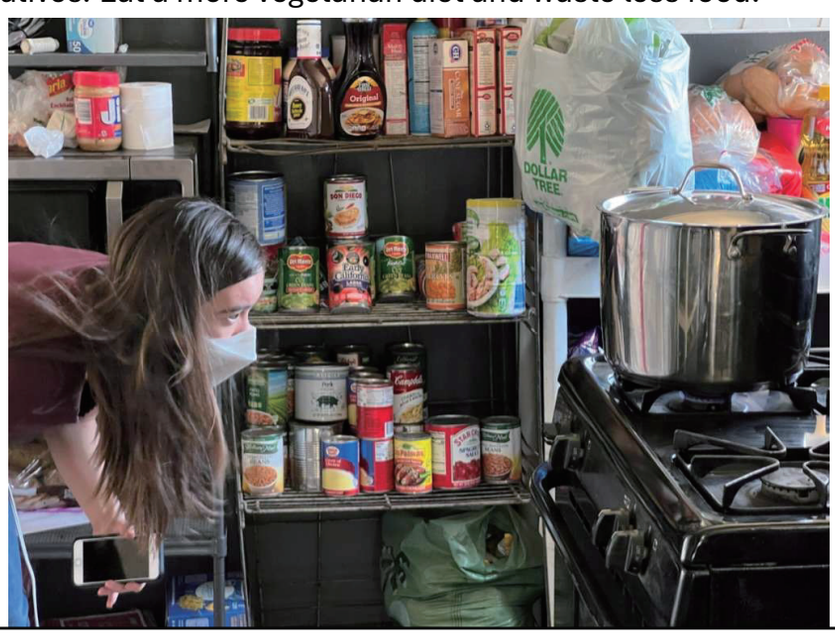
Robert B. Jackson,[†,‡,*] Adrian Down,[†] Nathan G. Phillips,[§] Robert C. Ackley,[∥] Charles W. Cook,[†] Desiree L. Plata,[⊥] and Kaiguang Zhao[†]





WE reached a similar outcome in Washington, D.C., the next year after mapping 6,000 pipeline leaks there. Washington Gas’s PROJECT*pipes* program began within a year as a forty-year effort to upgrade D.C.’s distribution system and reduce methane leaks. The local Public Service Commission concluded it would enhance safety and reliability for 165,000 customers.

How can we reduce methane emissions *individually*? Most methane is used to heat our homes and buildings. Replace your gas or propane stove and other appliances with electric alternatives. Eat a more vegetarian diet and waste less food.



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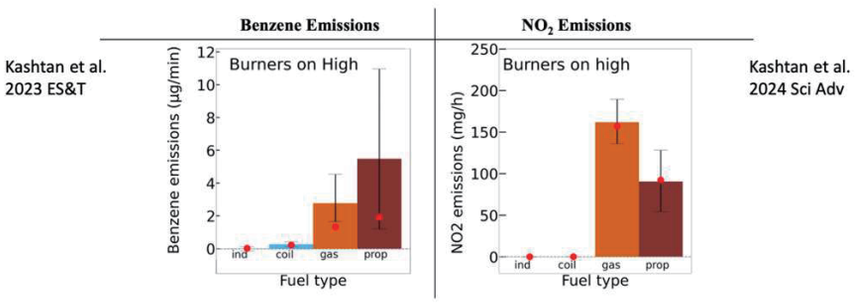
How can we reduce methane emissions *individually*? Most of the methane we consume is burned to heat our homes and buildings. To reduce your own emissions, you can eat a more vegetarian diet and waste less food. We can also replace our gas or propane stoves and other appliances with cleaner electric alternatives. Doing so helps the climate and allows us to breathe cleaner air.

You wouldn't willingly breathe air pollution from your car. Why breathe it from your stove?

Fuel choice dictates indoor air pollution. It's the flame not the food.

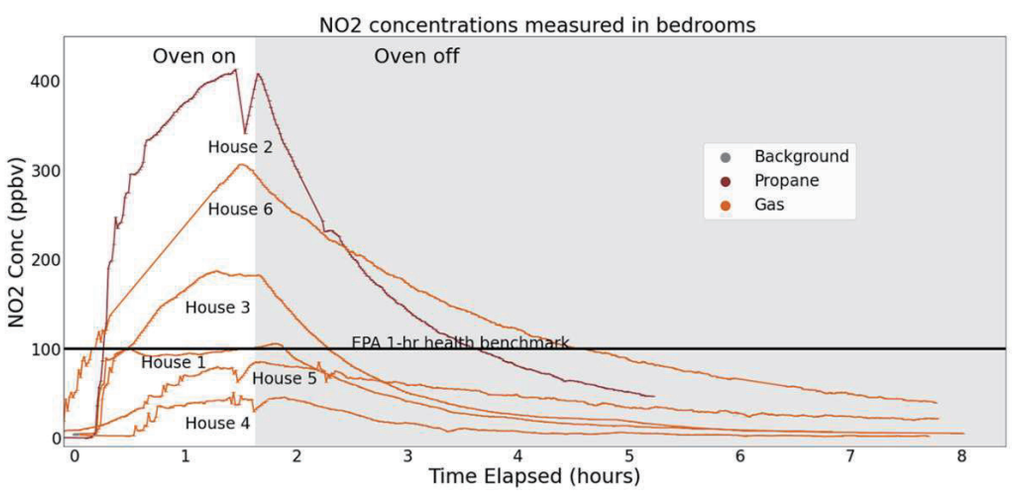
Stoves that burn gas and propane produce substantial benzene, nitrogen dioxide, and carbon monoxide. Electric and induction stoves produce none.



You can reduce risk through ventilation and behavioral changes, but you can't eliminate it.

You would never willingly stand over the tailpipe of your car breathing in air pollution from its exhaust. And yet we stand over a gas or propane stove day after day, meal after meal, breathing in the same pollutants. And unlike your ca, your stove has no catalytic convertor! As shown here, stoves that burn gas or propane produce carcinogenic benzene, asthma-triggering nitrogen dioxide, and toxic carbon monoxide. Electric and induction stoves produce none of this pollution. We spend 90% of our time indoors. Improving air quality indoors should therefore be just as big a priority as improving air quality outdoors.

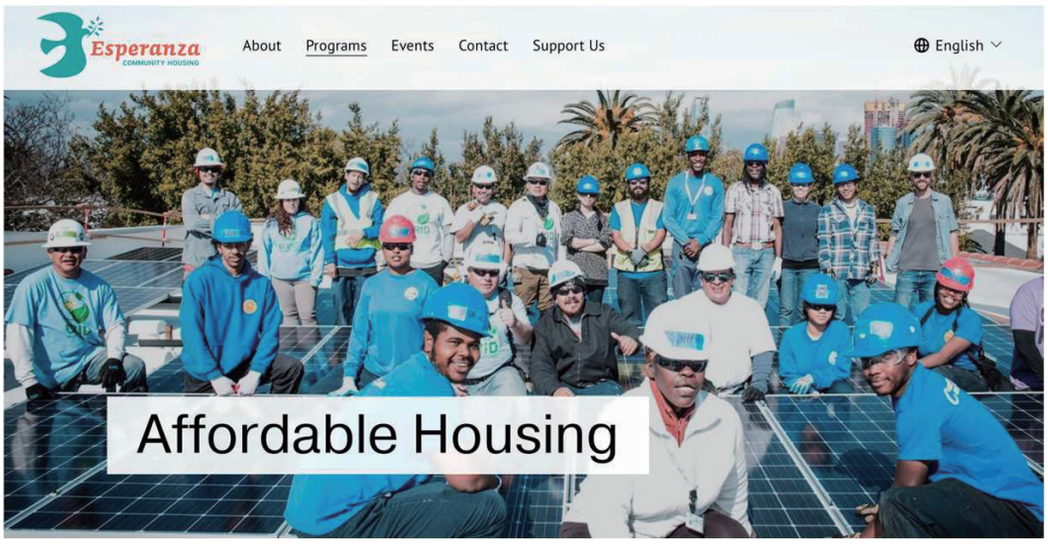
When you burn natural gas or propane indoors, NO_2, benzene, and other pollutants from the kitchen travel throughout your home to distant bedrooms, sometimes staying above health benchmarks for hours.



Kashtan et al. 2024 Sci. Adv.

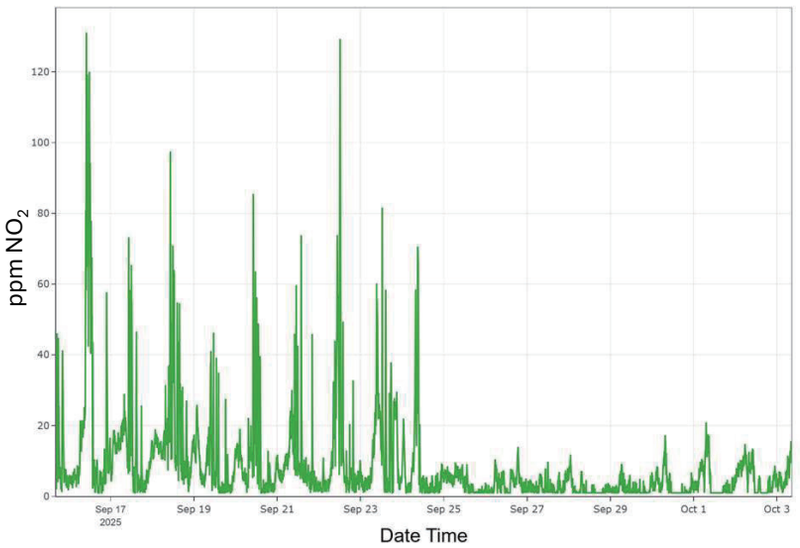
When you burn natural gas or propane indoors, NO_2, benzene, and other pollutants from the kitchen travel throughout your home to distant bedrooms, as shown here, sometimes staying above health benchmarks for hours. Here, you see concentrations of nitrogen dioxide in the bedrooms of six homes rise within half an hour of turning a gas stove on. In three of the homes, NO2 concentrations rise above the one-hour regulatory benchmark (the dark horizontal line) and stay over this threshold for hours even after the stove is off.

We need social movements as much as new technologies to solve the climate crisis. We're working with community partners (Central CA Asthma Collaborative, Esperanza, and Sustento) to document the health benefits of replacing gas with electric appliances in lower-income communities, such as this 30-unit public-housing complex in Los Angeles.



We need social movements as much as new technologies to solve the climate crisis. We're working with community partners (Central CA Asthma Collaborative, Esperanza, and Sustento) to document the health benefits of replacing gas appliances with electric alternatives in lower-income communities, such as this 30-unit public-housing complex in Los Angeles. In each apartment, a gas stove was replaced with a cleaner induction stove.

New results for a home in the Esperanza complex: NOx concentrations in a kitchen before and after replacing its gas stove with an electric induction stove (same apartment, same family). The induction stove eliminates all of the dangerous spikes in NO_2 levels. Clean energy is better for the climate and better for our health.



This figure shows NOx concentrations in a kitchen of the Esperanza complex before and after replacing its gas stove with an electric induction stove. It's the same apartment and the same family cooking. Notice how exchanging the gas stove for an induction model eliminates all of the dangerous spikes in nitrogen dioxide levels. Clean energy is better for the climate and better for our health.

I am donating my Blue Planet Prize funds to Stanford University, which will match the funds, to form a new program in:

Electrification for Health

Stanford University

Stanford WOODS INSTITUTE for the ENVIRONMENT

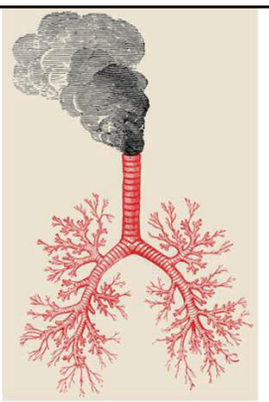
I am donating my Blue Planet Prize funds to Stanford University, which will match the funds, to form a new program in Electrification for Health. We will work to reduce greenhouse gas emissions and improve human health and air quality in lower-income homes around the world.

OPINION

BINYAMIN APPELBAUM

Enough About Climate Change. Air Pollution Is Killing Us Now.

April 19, 2022



Worldwide, one in five deaths is caused by burning fossil fuels—ten million senseless deaths a year—when cleaner, safer fuels are already available (Vohra *et al*. 2021).

SCIENTIFIC AMERICAN

APRIL 4, 2017

Forget about Climate Change

We should be embracing energy efficiency and the low-carbon economy because they promote jobs, national security and human health

BY ROB JACKSON

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Promoting clean energy does more than help solve the climate crisis. It makes us safer and healthier. Worldwide, one in five deaths is caused by burning fossil fuels—ten million senseless deaths a year—when cleaner, safer fuels are already available. We should embrace fossil-free energy because it promotes jobs, improves national security, and makes us healthier—as well as helping to solve the climate crisis.

Climate action will make us healthier. Past environmental transformations already have:

1) Japan was the first country to ban leaded gasoline. Since then, lead levels in the blood of our children have dropped 96%.

2) The Montreal Protocol protects the ozone shield and all life on Earth. It has saved millions of deaths and billions of skin cancers.

3) A half century of benefits from the U.S. Clean Air Act saves hundreds of thousands of lives a year at a 30-fold return on investment.

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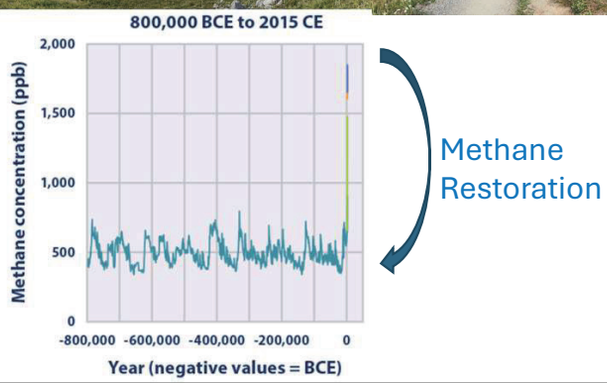
My first homework assignment in every class is for students to find things that are better today than they were fifty or a hundred years ago. The list is long: ife expectancy and childhood mortality. Water and air quality. The decline of global poverty, despite the injustices that remain.

The list of successes gets even longer with improvements based on targeted regulations. Since Japan became the first country to ban the sale of leaded gasoline in 1986, lead levels in the blood of our children have dropped 96 percent. The global ban on leaded gasoline saves the world two-and-a half trillion dollars a year and has literally made us smarter. Lead pollution from burning gasoline lowered the IQ of hundreds of millions of people born in the last century.

The Montreal Protocol to protect the ozone shield is the world's greatest environmental achievement. The phaseout of ozone-destroying CFC gases has saved billions of skin cancers and millions of cataracts worldwide.

Finally, half a century of action through the bipartisan Clean Air Act in the United States continues to save hundreds of thousands of lives a year at a thirtyfold return on investment. Workers are healthier and more productive. We breathe easier and pay lower medical expenses related to air pollution.

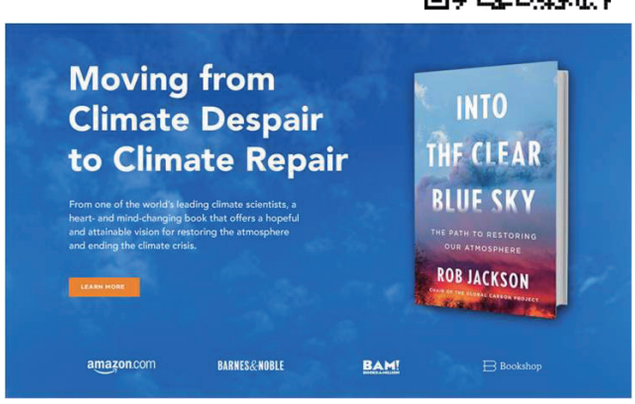
This is my dream:



This is my dream. I hope to restore the atmosphere to preindustrial levels of methane within the next few decades. Doing so will cool the Earth and save lives by reducing surface ozone pollution. It's the only greenhouse gas that can be restored within the lifetime of anyone in this room. I hope I live to see it.

Thank you for listening. And thank you for the Blue Planet Prize!

rob.jackson@stanford.edu



Thank you for listening, and thank you for the Blue Planet Prize! I am deeply grateful.