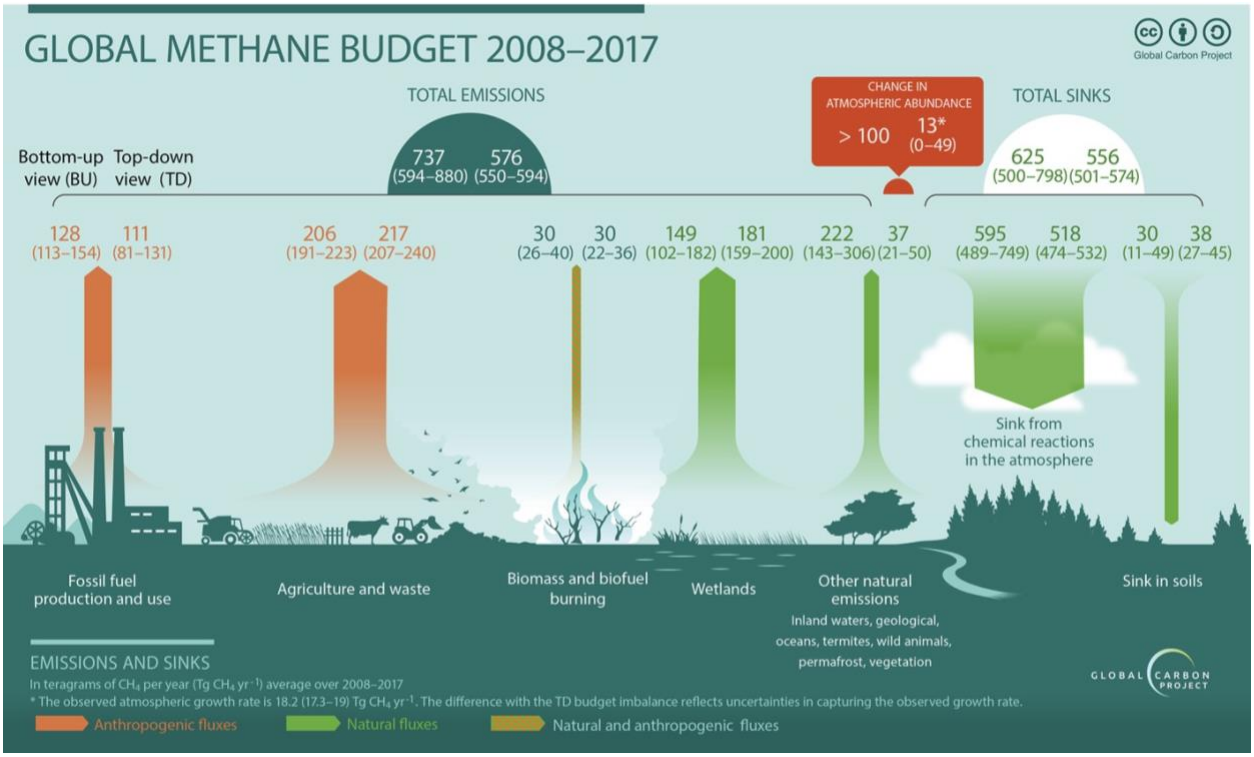
F. Meth*ane*

In 2016, methane (CH_4) accounted for about 10 percent of all U.S. greenhouse gas emissions from human activities. Human activities emitting methane include leaks from natural gas systems and the **raising of livestock**. Methane is also emitted by natural sources such as natural wetlands. In addition, natural processes in soil and chemical reactions in the atmosphere help remove CH_4 from the atmosphere. These interacting forces are summarized in the following figure.

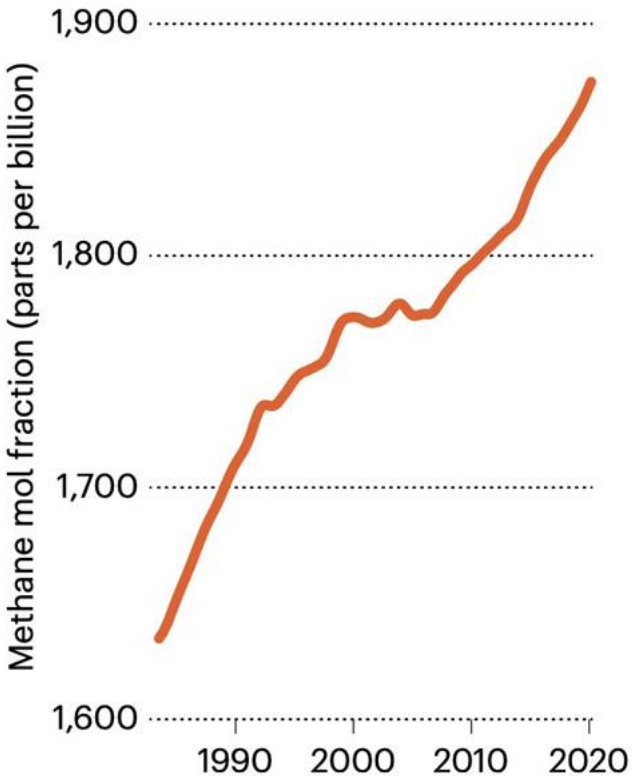


Global methane budget for the 2008–2017 decade. Both bottom-up (left) and top-down (right) estimates (Tg CH_4/yr) are provided for each emission and sink category, as well as for total emissions and total sinks. Biomass and biofuel burning emissions are depicted here as both natural and anthropogenic emissions (Saunois, et al 2020)

Methane's lifetime in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 is more efficient at trapping radiation than CO_2. Pound for pound, **the comparative warming impact of CH_4 is more than 25 times greater than CO_2 over a 100-year period.** The following are some of the major issues relevant to methane.

1. Methane Levels are increasing.

Global methane emissions have risen by nearly 10% over the past two decades, resulting in record-high atmospheric concentrations of the powerful greenhouse gas (Nature,2020).



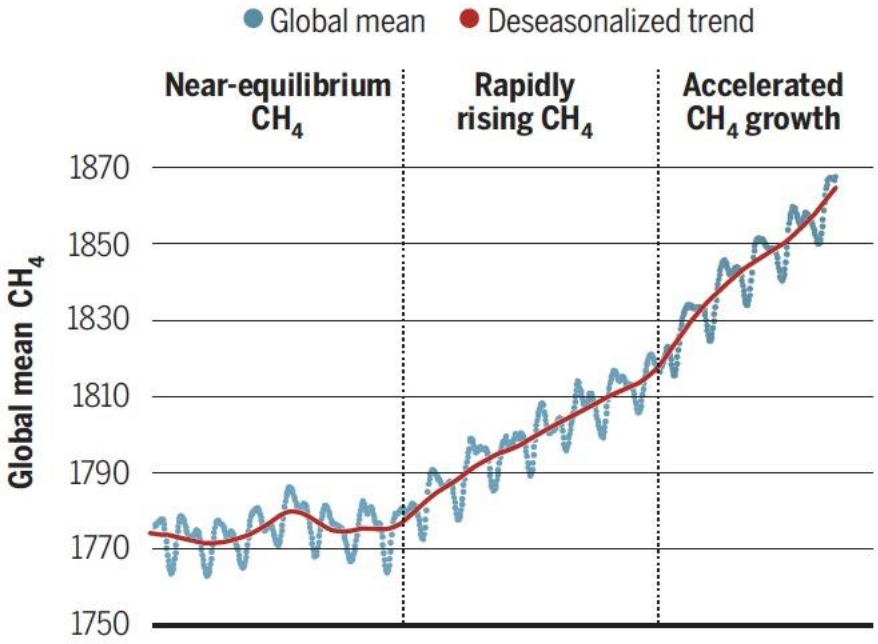
In 2017, the latest year for which comprehensive data are available, global yearly emissions of the gas reached a record **596 million tons**, according to scientists with the Global Carbon Project, which tracks greenhouse gases.

Annual emissions have increased by about 50 million tons from the 2000–06 average, mainly driven by agriculture and the natural-gas industry, the scientists report in two papers (Saunois et al. 2020; Jackson, et al. (2020). Atmospheric concentrations of the gas, which stood at 1,875 parts per billion last year, are now more than 2.5 times higher than preindustrial levels (see 'Record high'). Methane contributes to global warming by trapping heat in the atmosphere.

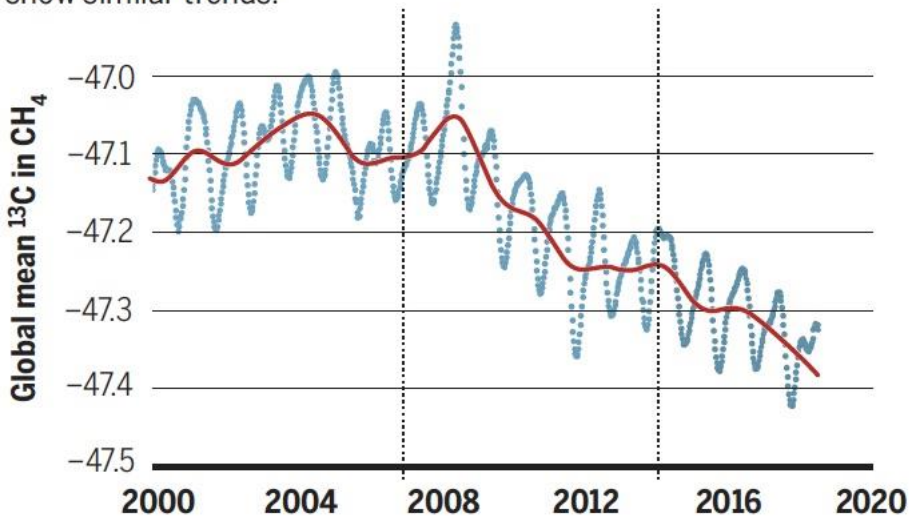
The following figure shows how methane levels are increasing over recent years (Fletcher and. Schaefer (2019). In 2007, the amount of methane in the atmosphere (CH_4) began to rise after a 7-year period of near-zero growth (see upper panel below). Recent research shows that a second step change occurred in 2014. From 2014 to at least the end of 2018, the amount of CH_4 in the atmosphere increased at **nearly double the rate observed since 2007** (see upper panel of the following figure).

Also starting in 2007, the proportion of ^{13}C in atmospheric CH_4 declined as CH_4 has risen (see bottom panel). The $^{13}C/^{12}C$ ratio in CH_4

depends on the sources of the CH_4 emissions. Release from **biogenic source**s (such as wetlands and agriculture - cattle) **reduces the proportion of ^{13}C in atmospheric CH_4,** whereas fossil emissions slightly increase this proportion and biomass burning emissions increase it strongly. Livestock inventories show that **ruminant emissions began to rise steeply around 2002 and can account for about half of the CH_4 increase since 2007.**

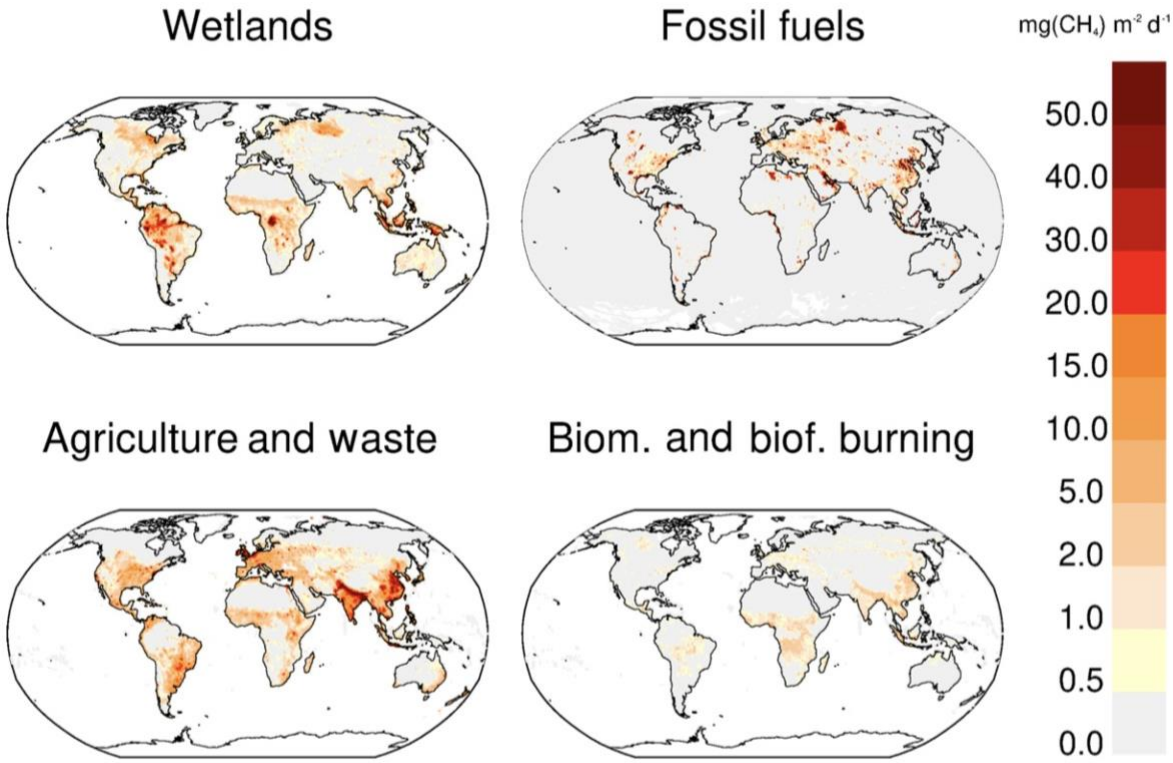


At the same time, the proportion of ^{13}C in CH_4 has been falling, providing insight into possible sources for the additional CH_4. Measurements from other observing station networks show similar trends.



The reasons for this increase are cattle and tropical forests, as well as coal mining in East Asia. An additional source may be the melting of permafrost in Siberia and other Arctic regions. This emphasizes the need **to both cut down on methane emissions and remove methane from the atmosphere.**

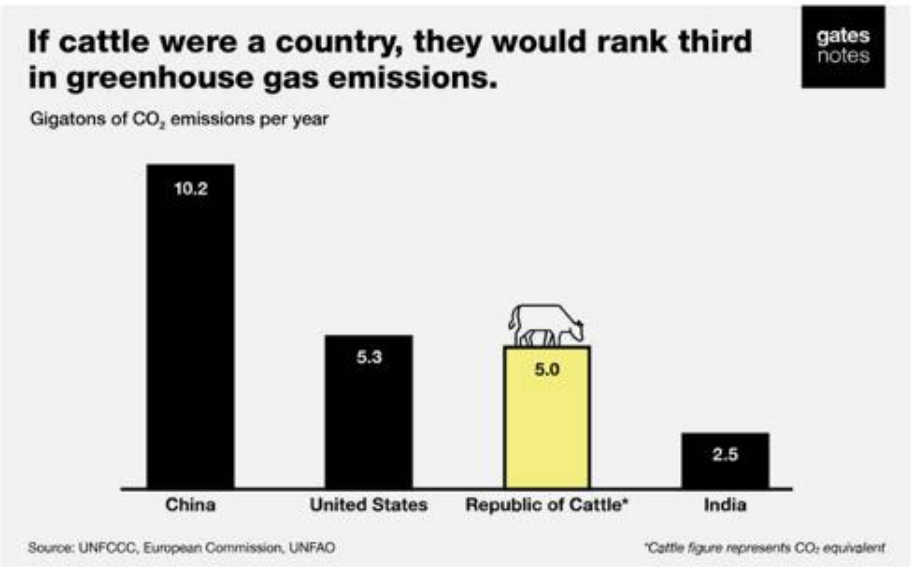
The report of Saunois et al (2020) on the global sources of methane are shown below.



Methane emissions from four source categories: natural wetlands (excluding lakes, ponds, and rivers), biomass and biofuel burning, agriculture and waste, and fossil fuels for the 2008–2017 decade (mg $CH_4/m^2/d$).

This shows that the Midwest United States, in addition to Argentina (Patagonia) central Africa, Europe and especially India and China are a significant source of agriculture (cattle) methane emissions.

2. Cattle and Methane



Cattle are a huge source of methane; in fact, if they were a country, they would be the third-largest emitter of greenhouse gases! *Gates Notes Oct 17,2018*

The atmospheric concentration of methane has risen dramatically in the modern age.

One method of decreasing the atmospheric methane concentration would be to **decrease the production of methane by cows**. This, in fact, has been achieved. Multiple reports have shown that **adding a small amount of red seaweed to cows diet dramatically decreases their production of methane** (Kinley et al, 2016). The compounds responsible for this effect are bromoform ($CHBr_3$), bromochloromethane (BCM) (CH_2BrCl) and di-BCM ($CHBr_2Cl$). Since these compounds are illegal to make in some countries because of risk to ozone depletion, it will be safer to make red algae commercially for cattle.

Companies that are helping

A number of feed companies and other companies are getting involved in supplying red algae and other types of methane suppressing feed to cattle ranchers. The following is a list.

Burger King (the following was taken from a July 1, 2020 article in the Washington Post by Tim Carman.)

Burger King is just now testing the market with its Cows Menu, which debuted at five restaurants, one each in Miami, Austin, Los Angeles, New York and Portland, Ore. The menu features a handful of burgers that will

swap out their traditional patty for one made with **Reduced Methane Emissions Beef**, a product that the chain developed with the help of two groups of scientists. Methane is a greenhouse gas emitted by ruminant animals, such as cows, and scientists say it warms the planet 86 times more than carbon dioxide over a period of 10 to 20 years.

While Burger King may be the first fast-food chain to capitalize on cattle feed designed to lower methane emissions, scientists have been tinkering with the diet of ruminant animals for years, with the same goal of reducing those troublesome gases. Researchers have added garlic, seaweed and even tannins, among other supplements, to cattle feed, and the results have been very encouraging. They've recorded methane reductions of 50 percent in dairy cows and 20 percent in beef cattle.

Burger King relied on a different supplement for its feed. The company worked with Octavio Alonso Castelán-Ortega, a professor with the Autonomous University of the State of Mexico, and his colleagues, who conducted the initial research that showed **lemongrass** could reduce methane emissions, Fernando Machado, global chief marketing officer for Restaurant Brands International, the parent company of Burger King, said in an email. Preliminary tests found that adding 100 grams of lemongrass to the feed reduced methane emissions by an average of 33 percent a day during the final three to four months of the cow's life. Ermias Kebreab, a professor with the University of California at Davis, and his team confirmed those initial results, Machado noted.

Sara Place, chief sustainability officer for Elanco, an international animal health company, said cattle methane emissions have already been dropping in the United States, thanks to improvements in animal nutrition, genetics and husbandry. "I see these [feed supplement] innovations as essentially adding to that," Place told The Washington Post. She said there has been a 30 percent drop in emissions between 1975 and today, based on Food and Agriculture Organization data.

Five Feed Companies (from GreenBiz article by Jesse Klein Aug 12, 2020).

1. Blue Ocean Barns is one of two companies on this list working with *Asparagopsis taxiformis*, a red seaweed. Blue Ocean Barns' trials at the University of California, Davis and other peer-reviewed studies on the seaweed have shown just a small sprinkling of the additive to the cow's diet can reduce methane emissions from 50 to 90 percent.

"We've met with over 50 ranchers, dairy producers, processors and food companies," said Joan Salwen, founder of Blue Ocean Barns. "All of them really want to see the carbon footprint from livestock go down and not by 20 or 30 percent, but really dramatically. None of them could have envisioned the 80 percent reductions that we are proving."

The seaweed prevents hydrogens from binding to carbon atoms in the gut, which creates methane. Instead, the cow releases carbon dioxide and hydrogen gas.

Blue Ocean Barns has been growing seaweed for two years, including on an oceanfront parcel in Hawaii with hundreds of acres available for cultivation. It plans to have products available by the end of 2021, focusing on California, where farmers are mandated by law to reduce methane emissions and where it already has connections through UC Davis. It has garnered investments from large dairy producers such as Mars, which awarded Blue Ocean Barns $200,000 to conduct a pilot with the company, and Land O'Lakes.

2. Symbrosia is also working on red algae. It, too, is only in the research phase and is completing its first trial on a sheep farm in New York. In Hawaii, Symbrosia is working on growing the algae, which can be quite finicky and difficult, and figuring out how to scale production. To get certified by the Food and Drug Administration, it will need enough product to run a full commercial trial. Symbrosia also has access to oceanfront property for growing.

"We're really familiar with the entire value chain and what this means to all the stakeholders," said Alexia Akbay, founder and CEO of Symbrosia. "We can bring the value the whole way through the supply chain. We really understand how to market the product and what we need to do on the technology to make it a marketable opportunity."

3. Alltech Alltech's product, Yea-Sacc, is already commercially available. This product, a yeast culture of *Saccharomyces cerevisiae,* doesn't directly reduce methane gas production. Instead, it increases the efficiency of cow milk production. Adding the yeast to the cow's diet creates a healthier gut microbiome, allowing the cow to turn grass into milk easier and quicker.

Alltech claims that Yea-Sacc provides higher sustained milk production per cow, therefore reducing the greenhouse gas emissions per unit of product. However, this approach might just lead to more, highly efficient cows and methane production could remain stable.

4. Mootral a Swiss agriculture company, has developed a garlic and citric acid natural feed supplement to reduce methane emissions from cows. The allicin in the garlic and the citrus extract in orange inhibits methane production in the rumen by as much as 23 percent, according to a UC Davis study.

While the seaweed additive might have better reduction rates, according to Mootral CEO Thomas Hafner, it is years away from marketability. What's more, those startups will have to overcome scaling obstacles in growing the seaweed, he said.

"Mootral has an advantage simply because we can tap into an existing supply chain," Hafner said. "We can tap into the existing garlic industry.

Have them grow our particular species that gives us a higher yield of active components. But there are 26 million tons of garlic being produced every year. If we were to serve 200 million cows, we were using 3 percent of that."

Mootral is exploring partnerships with brands all over the globe, including Brades Farm, which produces climate-conscious milk perfect for baristas.

5. Agolin Ruminant Agolin has had a methane-reducing product on the market since 2008, however it markets the additive to farmers as a milk production booster. The product is a blend of essential oils from herbs such as cilantro that create a healthier, more productive and less methane-producing gut biome in the cow. "It's adjusting the profile of the rumen microbiome," said Michael Roe, commercial director of Agolin. "It's suppressing some microbiomes, which allows others to proliferate. We're not interfering directly with chemical processes. I would say more sort of shifting the population profile within the rumen very slightly." An animal research trial showed an 8.8 percent reduction in methane per day; other studies showed a 15 to 20 percent reduction per kilogram of milk production. The next step for Agolin, and any methane-reducing additive product, is to get its methane claims verified by the FDA and be able to market the product as methane-reducing. No company has gotten this stamp from a regulator yet.

"For whatever company breaks through, it would pave the way for others," Roe said. "It's also a challenge for the FDA. They've never made an [methane-reducing] approval. How are they deciding to assess these products? The challenge is on both sides. The companies have to have a good enough dossier that can get through, and the FDA has to decide where the bar should be."

Other Organizations

Volta Greentech In a new factory on the Swedish coast, a startup called Volta Greentech will soon begin commercial production of *Asparagopsis taxiformis*, a type of red seaweed that’s never been grown before on land. The seaweed is being farmed because it has a unique ability to fight climate change: When it’s added to cattle feed, the cows that eat it burp less methane, a potent greenhouse gas that’s a major contributor to global emissions.

The company, a little over a year old, started by chance when one of the founders saw a story on Reddit about research on the methane reducing potential of the seaweed. “I was a student at the time, and I was thinking, why is this research not getting out to farms if the results are so promising?” says Fredrik Åkerman, cofounder and CEO of Volta Greentech. “I started looking into how this research could be commercialized.”

Moss Landing Marine Laboratories Graduate students and researchers at California’s Moss Landing Marine Laboratories have scoured coastal waters, collecting seaweed in the hopes of finding a native species

that could help gassy cows. As pressure to reduce heat-trapping gases in the atmosphere mounts, an increasing body of research has shown that seaweed added to cattle feed could dramatically reduce livestock's impact. The challenge: where will the enormous supply of seaweed—enough to impact millions of cows—come from? And at what cost?

Most scientists have focused on one red seaweed species *Asparagopsis taxiformis*—which thrives in tropical and sub-tropical climates. While asparagopsis can be found in Southern California, its habitat in the U.S. is relatively small since it's a warm-water species. There are also concerns about it being invasive.

The hope is that a native seaweed alternative can be found to allow for sustainable cultivation in California. Simultaneously, researchers are studying the local *Asparagopsis* strains, to better understand their life cycle and how they could be safely cultivated at a large scale in on-land tanks or off the California coast.

Currently, the *Asparagopsis* used for research is imported from Australia, Asia, and Europe. It is not cultivated or sold anywhere, so divers must be hired to pick it in the wild, making it expensive. If it were grown at scale for cattle to reduce emissions, it would cost less; most seaweed grown on ocean farms around the world is already quite cost-efficient.

"If we're going to use seaweed to feed cows and do it on an impactful scale, there's an interest in local sources, so we're not sticking it on a boat, burning a bunch of fuel and bringing it to California," said Jen Smith, an associate professor at the University of California, San Diego, who studies *Asparagopsis* native to the state. "We're interested in growing it here."

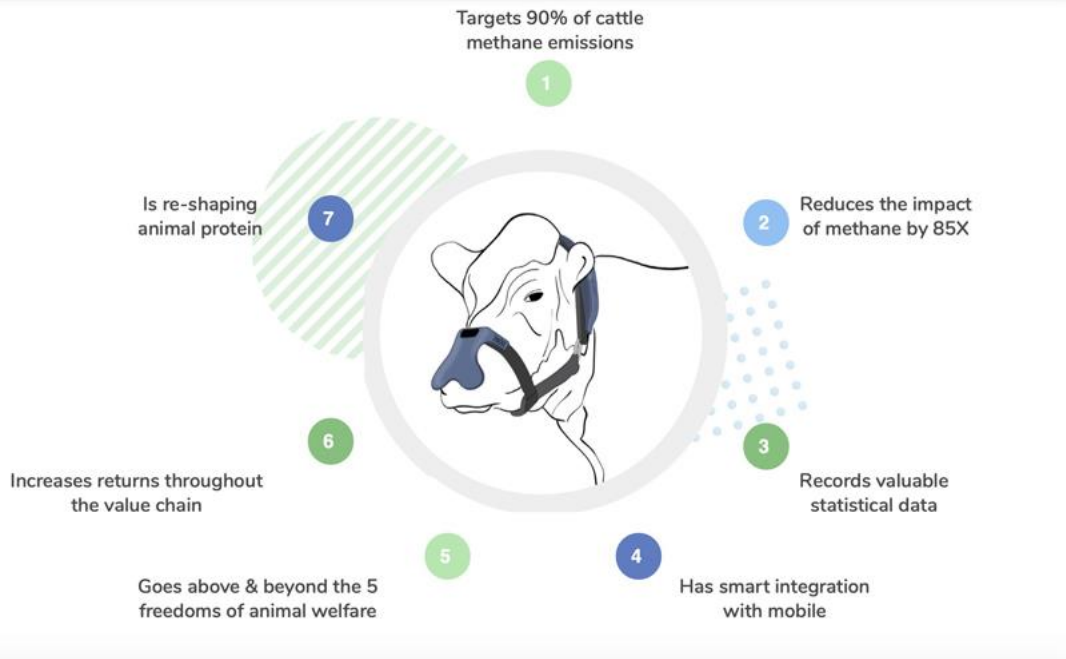
The urgency to find a solution picked up in 2016 when California passed a landmark bill that mandates a 40 percent reduction in methane emissions by 2030. The state's biggest contributors of methane gas are its 1.7 million dairy cows and 650,000 beef cows.

Elm Innovations is another company doing research on the use of red seaweed in controlling methane from cattle.

Zelp

Another method of reducing the release of methane by cows is to oxidize the methane emissions from the nostrils of cows. **Zelp** is a company in London that is promoting the use of a mask for cows that oxidizes the methane present in cattle exhalations. Up to 95% of methane emissions come from the mouth and nostrils of the animal. Zelp technology measures, captures and oxidizes methane in real-time, with the capacity to target vast quantities of methane.

The cattle wearable attaches to regular halters in a non-intrusive way and, as well as converting methane, it has the added capacity to improve animal welfare by capturing, analyzing and processing large amounts of data on each animal.



The novel aspect of this technology lies in the process we have developed for oxidizing the highly diluted methane exhaled by cattle. This process incorporates novel catalytic technology that has been successfully tested in laboratories with proven catalytic efficiency under conditions that replicate those on the cow. This technology has also been tested through numerous behavioral trials which evaluate the impact of the wearable on animal behavior as well as production yields, rumination, rest and activity periods and feed intake.

Because the feed companies themselves are addressing the problem of cattle and methane, the Comings Foundation feels that it is probably better handled by them, freeing us to concentrate on other areas of methane control.

Cows Are Not that Bad?

For an alternative view to the role of cattle in methane production and global warming see the response of the livestock framers, i.e., Fake Moos. Don't Believe the Lies. Why Cattle are Good for the Environment. In **Sustainable Farming** 4:Spring 2019.

3. Tropical Forests and Methane

The tropical wetlands have been found to emit large amounts of methane into the atmosphere (Tollefson, 2019). Further research on this is needed but this source of methane would be hard to combat other than by removing it from the atmosphere.

4. The Removal of Methane from the Atmosphere with Solar Chimneys

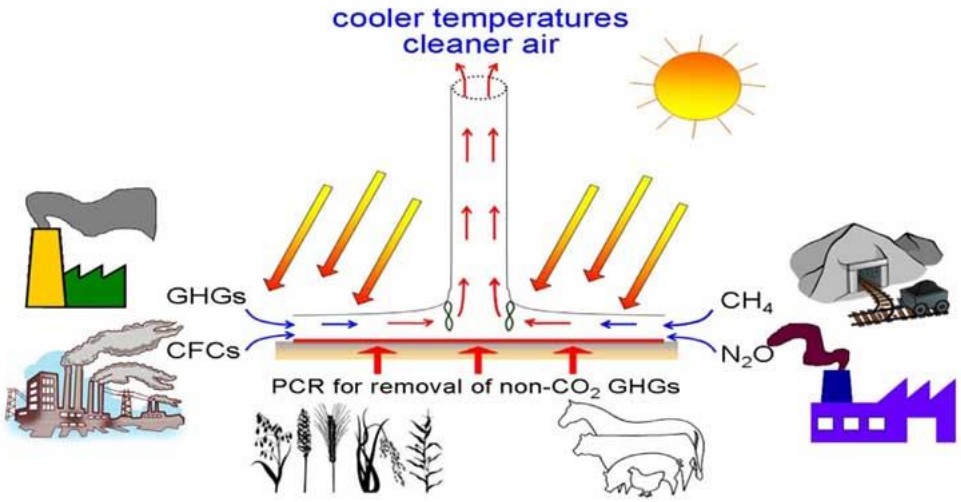
Even if humans stop combusting fossil fuels and discharging CO_2 into the atmosphere, the average global temperature of the earth will continue to increase for the rest of the century for several reasons.

First, the **long lifetime of CO2 (estimated in the 100,000-year range**) means that the excess atmospheric stocks (515 Gt Carbon) would continue to drive radiative forcing and global warming for many decades.

Second, even if atmospheric concentrations were to decrease, **CO_2 would out gas from the oceans** and offset this decrease, because of the dynamic equilibrium between the CO_2 in the atmosphere and the carbonates HCO_3i/CO_3^2i dissolved in the oceans.

Third, there is the contribution of other GHGs, besides CO_2, which together account for about 34% of radiative forcing. **Even if all excess anthropogenic atmospheric CO_2 were removed, radiative forcing would only be reduced by half. The following is a proposal on how to remove the other half.**

A hybrid of a **Solar Chimney Power Plant (SCPP)** and a **Photo-Catalytic Reactor (PCR)** has been proposed as a method of removing non-CO_2 greenhouse gases. The concept is shown here (deRichter et al. 2017; Schlaich, 1995; Schlaich, et. al.2005).



The SCPP is an established concept that generates electricity in a solar updraft tower incorporating axial-flow turbines. Hot air is supplied to the tower by a large solar hot air collector. A conventional **SCPP-PCR** is composed of 4 principal components:

1. A very large collector for the greenhouse effect,
2. A tall chimney for the stack effect,
3. A thermal energy storage layer (water) to store the solar radiation for night-time operation,
4. Several turbines to generate renewable electricity which is carbon free.

PCR can be incorporated in the SCPP by coating its collector with a photo catalyst, such as TiO2, which is able to transform methane and other non-CO_2 GHGs into less harmful products.

Transformation of 1 kg of methane into 2.75 kg of CO_2 reduces its climate change effect by 90% and is equivalent to removal of 25.25 kg of CO_2 from the atmosphere.

The SCPP component produces sustainable decarbonized renewable energy. Photo catalysis avoids the need for capture and sequestration of these atmospheric components.

World-wide installation of 50,000 SCPPs, each of capacity 200 MW, would generate a cumulative 34 PWh of renewable electricity by 2050. These SCPP-PCP devices would reduce or stop the atmospheric growth rate of the non-CO2 GHGs and progressively reduce their atmospheric concentrations.

The Comings Foundation could supply the funds to build a 200 MW prototype proof of concept in the US.

5. Development of non-greenhouse gas refrigerants

The book ***Drawdown*** compiled a list of 100 projects that would help combat global warming and assessed the relative impact of each. Number 1 on the list was the release of refrigerants into the atmosphere.

One kilogram of a typical refrigerant gas contributes as much to the greenhouse effect in our planet's atmosphere as **two tons of carbon dioxide**, which is the equivalent of running a car uninterruptedly for six months. On method of combating this is the development on non-greenhouse gas refrigerants. Materials called **plastic crystals** have been found to undergo huge temperature changes when subjected to small pressures near room temperature. Such materials could form the basis of save future refrigeration technologies. (Li and Yukinobu (2019). The ComingsFoundation.org will support the development of this new technology.

6. Support Methane Satellite Fred Krupp of the Environmental Defense Fund is obtaining TED Audacious Project funds for the launching of a methane detecting satellite. This will identify oil and gas companies around the world whose facilities are releasing methane, often unknown to them.

Experience shows that when informed of this release they often fix the problem. This approach may reduce the world-wide release of methane by 50 percent. Go to **YouTube**, search for **Methane Satellite Fred Krupp TED talk.**

In addition, some of the critical data regarding tropical methane production comes from a monitoring station on the Ascension Island in the Atlantic. Funding for this station is threatened.

Given the importance of methane as a greenhouse gas, the Comings foundation will attempt to support several of the above approaches.

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