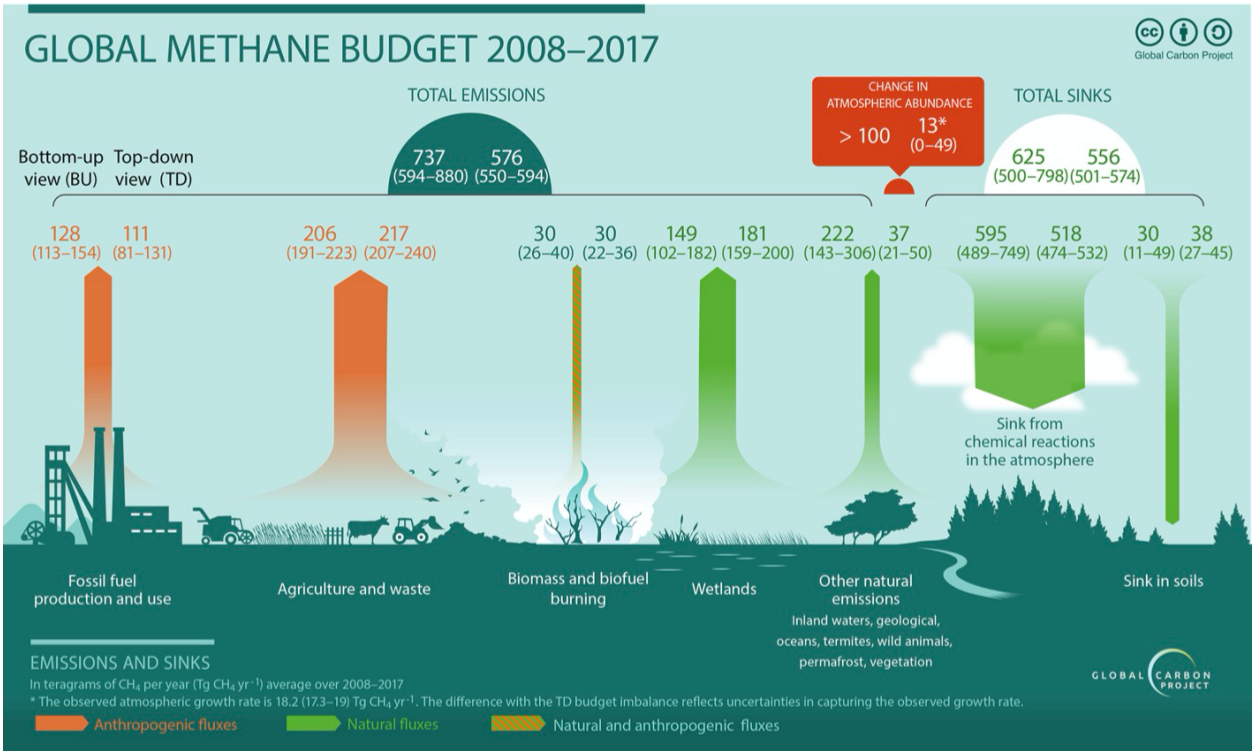
F. Meth*ane*

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.



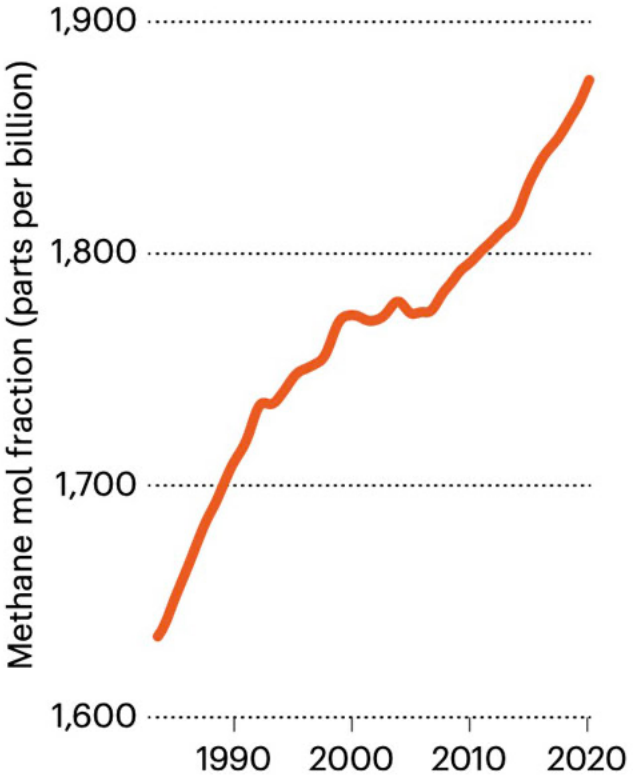
Global methane budget for the 2008–2017 decade. Both bottom-up (left) and top-down (right) estimates (Tg CH_4/yr) are provided for each emission and sink category, as well as for total emissions and total sinks. Biomass and biofuel burning emissions are depicted here as both natural and anthropogenic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



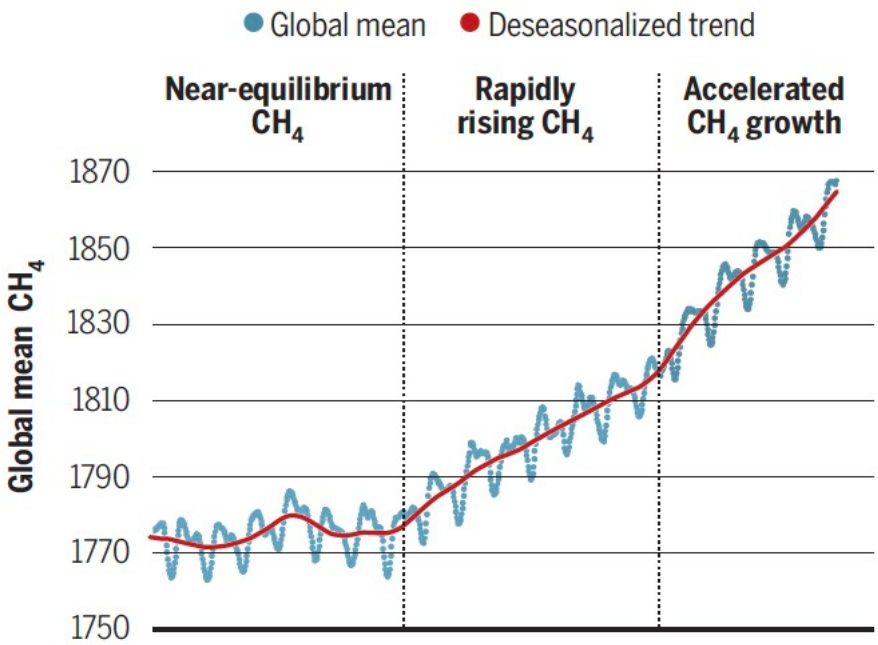
In 2017, the latest year for which comprehensive data are available, global yearly emissions of the gas reached a record **596 million tons**, according to scientists with the Global Carbon Project, which tracks greenhouse gases.

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

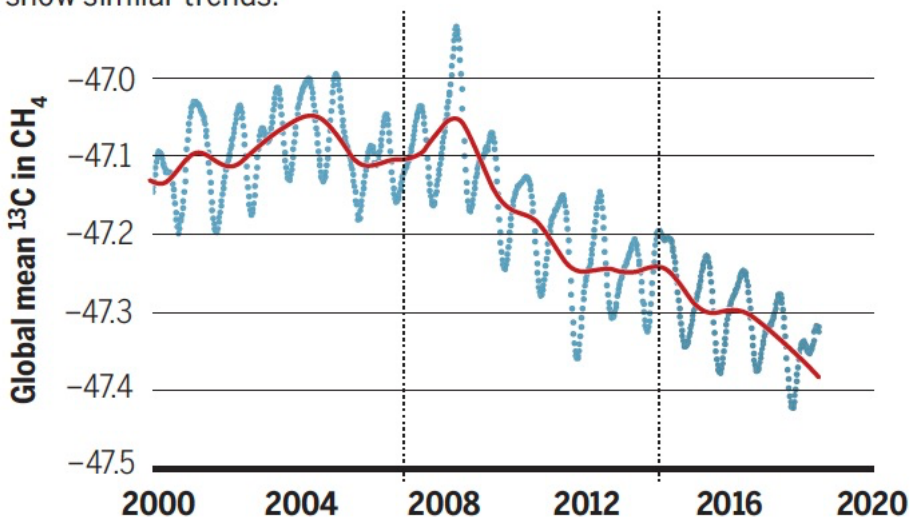
the gas, which stood at 1,875 parts per billion last year, are now more than 2.5 times higher than preindustrial levels (see 'Record high'). Methane contributes to global warming by trapping heat in the atmosphere.

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 sourc**es (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.**

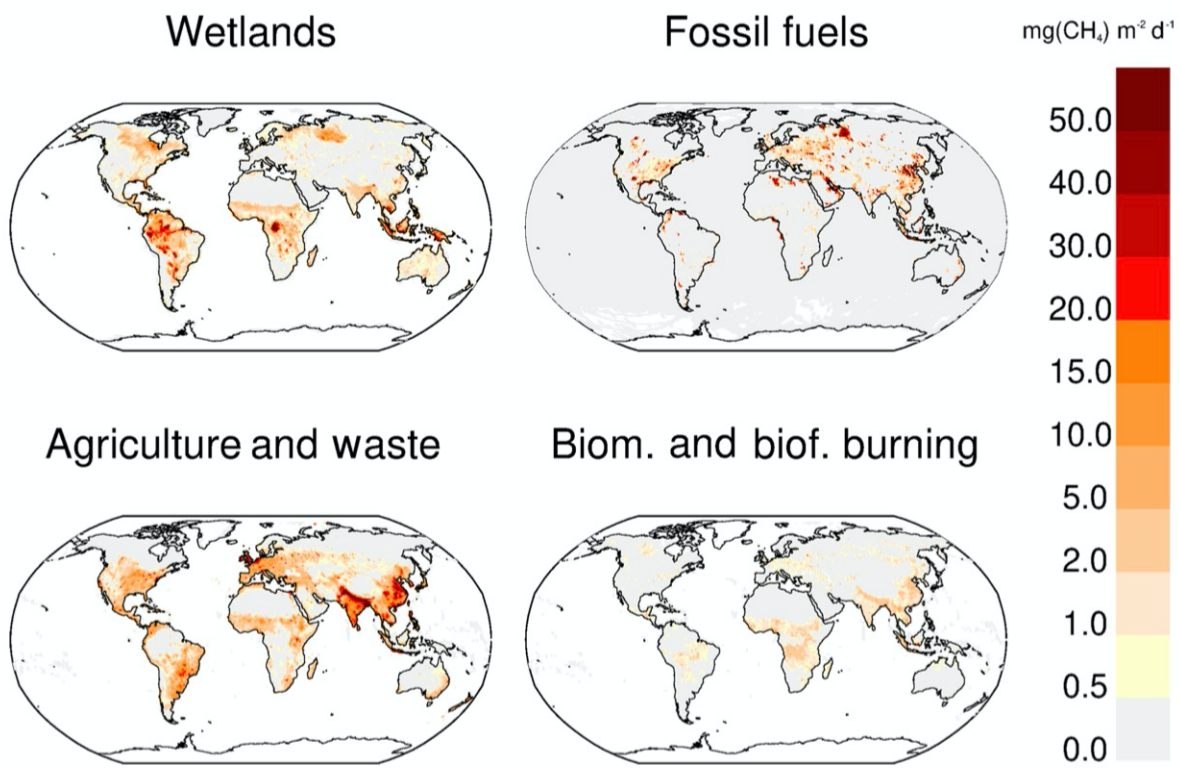


At the same time, the proportion of ^{13}C in CH_4 has been falling, providing insight into possible sources for the additional CH_4. Measurements from other observing station networks show similar trends.



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.**

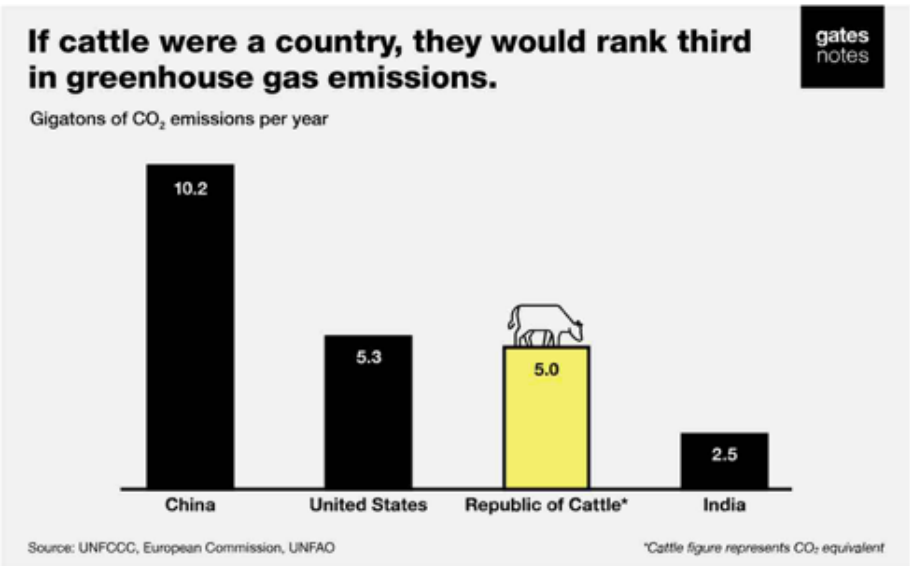
The report of Saunois et al (2020) on the global sources of methane are shown below.



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.

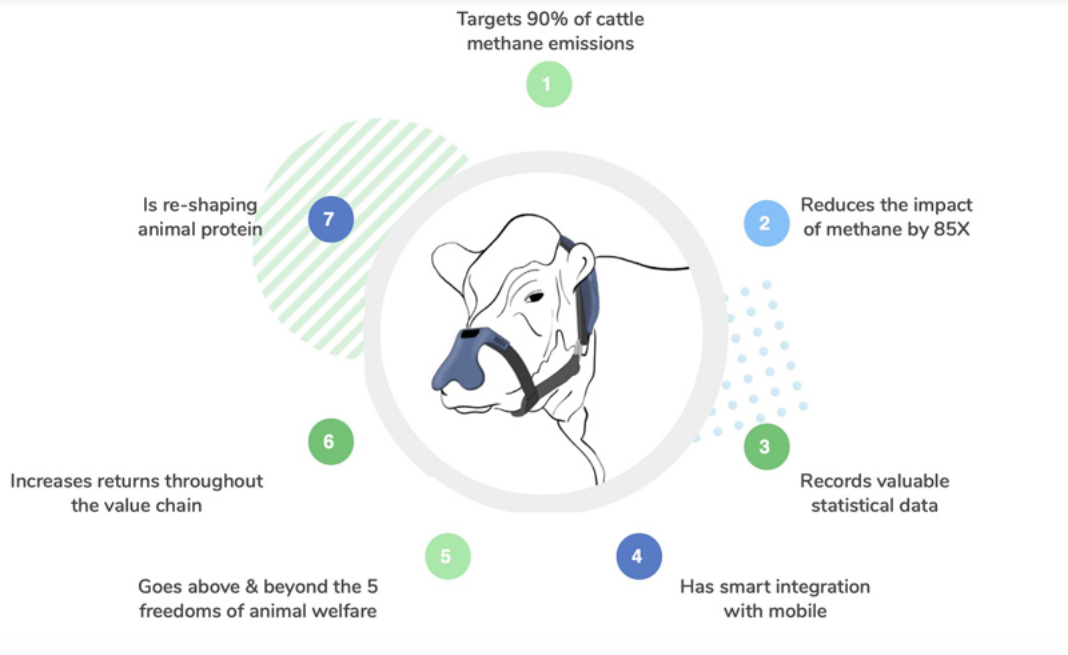
One method of decreasing the atmospheric methane concentration would be to **decrease the production of methane by cows**. This, in fact, has been achieved. Multiple reports have shown that **adding a small amount of red seaweed to cows diet dramatically decreases their production of methane** (Kinley 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. Research needs to be done to determine the best methods for this. The Comings Foundation will provide grants to accomplish this. This could be **integrated this with the ocean farming of seaweed** (see ocean farming).

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

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.

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.

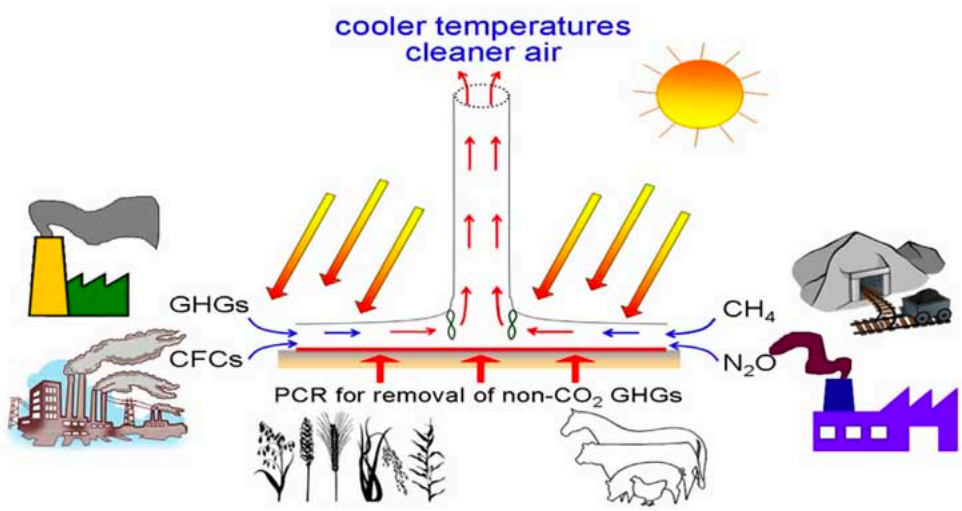
First, the **long lifetime of CO2 (estimated in the 100,000-year range**) means that the excess atmospheric stocks (515 Gt Carbon) would continue to drive radiative forcing and global warming for many decades.

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.

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. (Nature 567:506-510, 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.

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