LEARNING ABOUT CLIMATE CHANGE

1.0 IN A NUTSHELL

The industrial revolution blossomed on easily-accessed fuels – fossil fuels. Those fuels are all carbon-based. They all produce lots of easily-accessed energy when burned to produce carbon dioxide (CO2).

Humans didn't know it to begin with but a carefully-controlled amount of CO2 is necessary to maintain a climate that is friendly to life as we know it. The earth, sometimes called "Mother Earth", and sometimes called "Gaea" developed a cooperation between different parts of its environment to keep CO2 at a level that kept the climate in control for thousands of years.

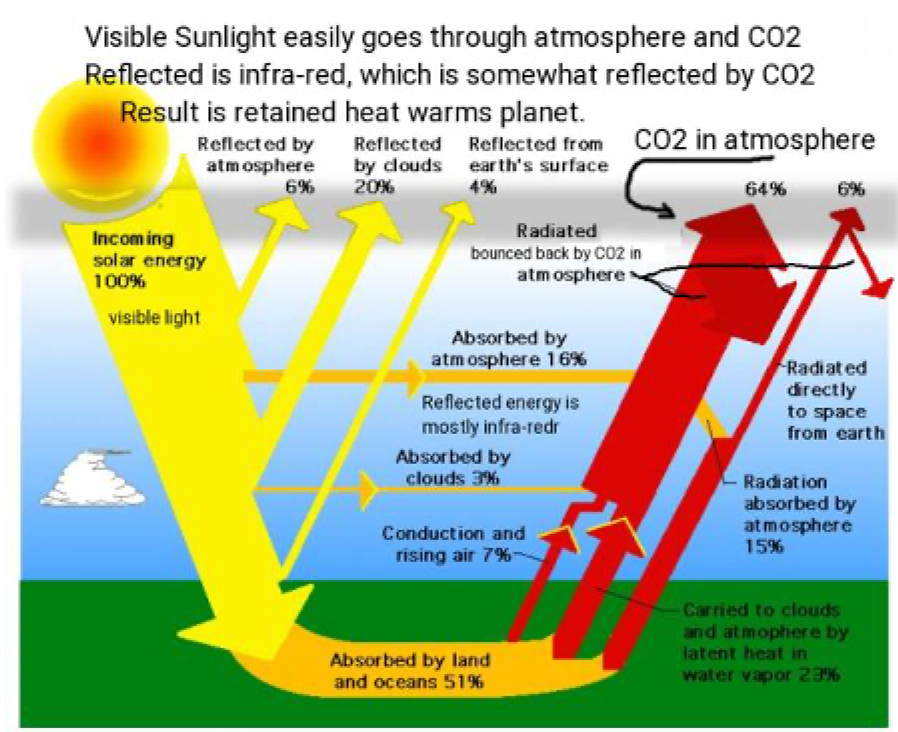


Figure 1. The effect of CO2

CO2 (and some other gases) act as a blanket. Sunlight energy enters our atmosphere and bounces off of whatever surface it runs into. The reflected energy is mostly infra-red energy as opposed to the visible light that came in. The CO2 keeps the infra-red energy inside the atmosphere. Increased CO2 keeps more energy in. More energy becomes heat and the temperature goes up.

The earth radiates energy as a “black body”, and the key information to know about that is more heat is radiated if the body is a higher temperature. So if we have more CO_2 in the atmosphere, the earth gets enough hotter that the black-body radiation grows just large enough to balance the incoming energy.

The burning of Carbon-based fuels did good things that allowed human civilization to grow as never before. Since doing so was dependent on the availability of abundant energy, and readily-available energy was carbon-based fossil fuels, our use of them grew on an exponential curve correlated to our population growth.

Thus, our disturbance of the atmosphere’s CO_2 balance went from being a slow disturbance to an ever-growing one. One that has nearly reached limits beyond which life forms such as ours and our food sources may no longer be so well supported on Earth.

That’s the beginning, but there are more layers. Remember, there was a feedback system that kept things in amazing control for about 800,000 years. This gave humans the “Garden of Eden” planet that allowed the transition from hunter-gatherer behavior to farming, and cooperative society with lasting communities and alliances.

But, our use of those fuels disturbed that premise with secondary consequences:

1. If temperature changes, it changes how the air carries water.
2. If the water in the air changes, that changes almost everything about the weather, because it moves air streams, and it changes where and when rain occurs.
3. If atmospheric CO_2 changes, so does the Ocean’s CO_2. See Ocean Acidification.
4. Both the ocean and the ground store huge quantities of methane, which can produce worse effects than CO_2.
5. Huge changes in the earth’s ability to support billions of people can come from the resulting increate of greenhouse gases.

2.0 CO_2

2.1 Carbon Dioxide in the Atmosphere

The first thing to understand is that the **industrial revolution** has contributed carbon dioxide (CO_2) to the atmosphere. This CO_2 joins CO_2 that was there naturally. For as long as humans have been on the planet, there has been an approximately-constant amount of CO_2 in the atmosphere. That amount has gone through fairly regular cycles of climbing to a higher level, then falling back to a starting point, then climbing again.

Higher levels of CO_2 blanket the earth and that causes solar warming of the planet. Lower levels allow more heat to escape and we have cooler temperatures. Thus, we have had ice ages and warm spells associated with the pattern seen above for hundreds of thousands of years.

Since the industrial revolution, human use of fossil fuels has added excess CO_2 into the air. This is more than the self-regulation of the earth has managed during those hundreds of thousands of years. In all the previous time, the CO_2 level in the atmosphere has not been more than about 285 parts per million. Now, the level has gone way higher, passing 350 parts per million and now passing 400 parts per million and still climbing rapidly.

The result has been a rise in temperature and rising sea level as glaciers melt.

2.2 **Carbon Dioxide in the Sea**

The rate at which CO_2 increased wasn't as fast as expected, however. For a while that was puzzling. Then it was discovered that CO_2 was being absorbed by the oceans at a faster rate than expected, leaving less in the atmosphere.

CO_2 in water is what produces the fizz in soda pop. It is a weak acid, but strong enough that you can put an egg in a jar of soda pop and the acid in the soda will dissolve the hard shell from the egg, leaving it soft. The egg's shell is made of calcium, and when it mixes with the CO_2 in the water, the result is Calcium Carbonate, which dissolves.

So, while the ocean "saved the planet" from experiencing as much solar warming as might have happened, there was another effect, and that is a problem that we only partially understand. Calcium is important to all plants and animals. In animals it produces our skeletons. Some animals, like humans, have skeletons inside their bodies. Other animals like clams and shrimp have their skeletons on the outside of their bodies.

Currently, the acidity (measured with "ph") in the Pacific Ocean varies with currents. Much of the time it is now so acidic that oyster "seed" (baby oysters) cannot create their shells, and will die. Some of the time the acidity lowers far enough that you can set seed out into the ocean and they do survive. As time goes on, more CO_2 will be dissolved from the atmosphere, and the portion of time that allows oyster seed to survive will decrease.

Carbon Dioxide (CO_2) that goes into the atmosphere doesn't always stay there. When the CO_2 is greater than historic levels, it will mean that the unbalance between CO_2 in the atmosphere and CO_2 in the oceans will be such that the oceans will absorb more CO_2 until things come back into balance.

This balancing first happens at the surface of the ocean. Then, the ocean currents take the more acidic water and mix it down to deeper levels and bring up fresher water, which continues the absorption of CO_2. Measurements of this absorption into different ocean layers has seemed to say that the mixing doesn't always happen at the same rates, and scientists have been surprised by the changing rates of absorption.

When the oceans have absorbed a surprising amount of CO_2, the amount left in the atmosphere has been lower than expected.

Dissolved CO_2 becomes carbolic acid, which increases the acidity of the oceans. Increased acidity is an important and problematic change because much sea life has exoskeletons. That means that their "bones" are their shells, which are made, like all bones, with lots of calcium. So, increasing ocean acidity gives sea life something like osteoporosis – i.e., calcium deficiency in their shell creation. For this situation, that problem starts at birth.

3.0 THE PRECAUTIONARY PRINCIPLE

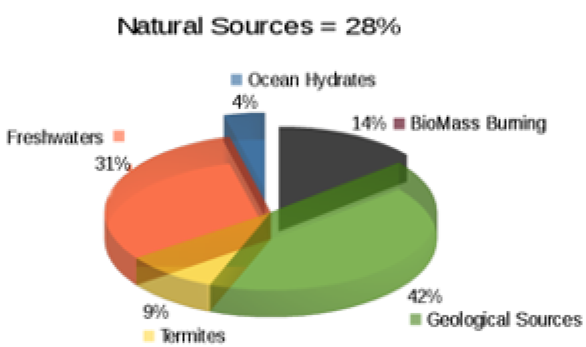
If you have a neighbor with a gambling problem, you don't just go next door and tell him/her they are putting the future of their family at risk, by exposing themselves to known risks that mathematically favor the casino. Because gambling addiction requires the intervention of professionals.

What do you do with Government committing the nation, your sovereign nation, to risks where you absolutely can't win, but the real problem is that it sets up their and your grandkids for a 100% sure loss of any habitable future? Knock on the door? Get a professional therapist? Knock the door down? OK, step back and study the risk so you can explain it to enough other neighbors to take ANY and all action because inaction is, in a real sense, terminal.

4.0 METHANE

4.1 Introduction to Methane

We know that the natural methane cycle involves natural sources of methane stemming from the anaerobic decomposition of decaying matter that is found in wetlands together with animal and termite digestion. The methane itself decomposes into CO_2 with a 12-year half-life. Before industrialization, the global methane source-sink balance was stable. The natural and anthropogenic sources of methane are depicted in Figure 1.



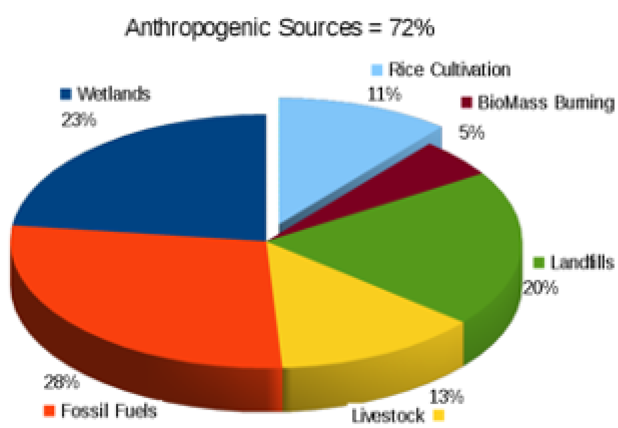


Figure 2 Sources of Methane

Since methane is such a powerful Greenhouse Gas, with 84x more global warming capacity than CO_2, it is possible for human-sourced methane to overdrive the planet's natural balance. Global warming is the response to the combined effect of accumulated CO_2 and CH_4 (methane) plus other pollutants.

Natural sources also include the release of methane captured in decayed matter frozen into permafrost in the Arctic. With the high increase in average annual temperatures in the Arctic (+5F), the natural response is to release that captivated methane.

We find in Figure 2 that the trend, before significant artic methane release, is toward increasing concentration every year, despite the CH4 half-life. The risk of a sudden release of Arctic methane in response to increasing Arctic temperatures would further increase GHG-driven Arctic methane releases. We do not know for certain how close the planet is to the Arctic temperature where methane release starts tipping uncontrollably past its current retention state.

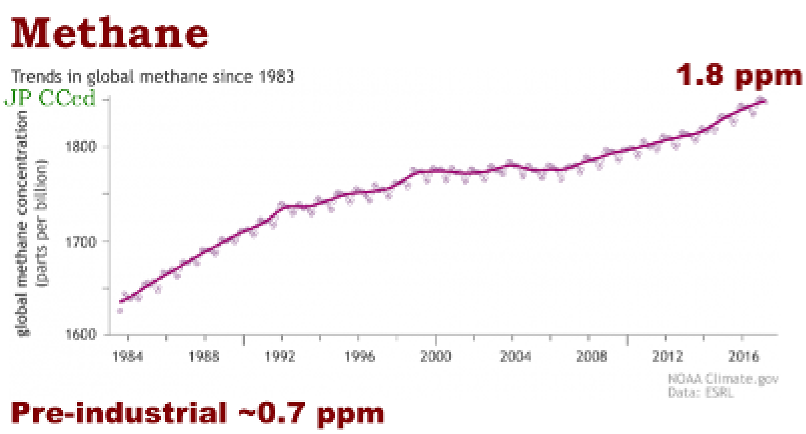


Figure 3 Methane Concentration History

Some evidence points to 1.5 deg C as a likely threshold for permafrost melt. An examination of caves in Siberia found geologic evidence that permafrost melting occurred at 1.5 deg C above the historic average temperature (New Scientist). Regarding the possibility of a methane runaway tipping point temperature, the same experts opined no risk, with no evidence given, because soil microbes consume some methane. This was before methane started forming post-blowout craters in Siberia.

The phrase "Methane Bomb" or sometimes "Arctic Methane Bomb" refers to a huge risk for an event that we can't accurately forecast. It has the opportunity to rip control away from humans and finish heating the planet past supporting life as we know it. As the video clip below puts it; If nature starts putting out global warming gasses as fast as humans are, now, then it will no longer save the situation for humans to stop putting their share out. It is a real risk, and should bring an urgency to attempts to stop CO2 emissions that has not been in anyone's serious planning, yet.

The issue is that a huge amount of methane has been stored in the arctic over millions of years. This was necessary to switch life on earth from anaerobic life (organisms for which oxygen is a poison) to aerobic life (organisms like us that breath oxygen). Almost all current animal life forms are aerobic, and they depend on the oxygen-tolerant plants on land and in the ocean to resupply the oxygen that we breath.

4.2 An Emergency Management Plan for the Onset of Methane Runaway.

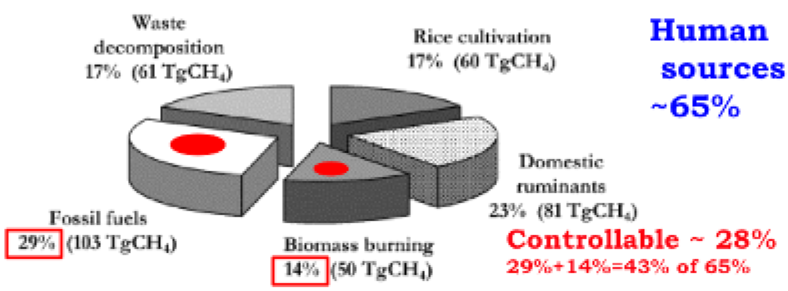
Given the dire consequences of exceeding the unknown Arctic Tipping Point temperature, a corporate-style risk management plan would be advisable. There is no such plan as we drive our planet forward into a risky unknown future. Maybe we should start one.

4.2.1 Risk Analysis

Human-sourced methane (65% before the tip) could conceivably be controlled and cut faster than the Arctic methane tips out. Which sources are controllable? The extent of controllability is depicted in Figure 3.

Rice cultivation cannot be stopped under any conceivable circumstances, nor waste decomposition, nor enteric methane from domestic ruminants. That leaves fossil fuels (29% of human sources) and biogas burning (14% of human sources), for a total of 43% of human sourced methane. This equates to 28% of all methane sources.

You would think there would be settled science on these existential questions. There is no question in science that is more consequential that that for runaway methane. It remains open and neglected. Even if you are not a problem gambler, but no definitive answers to these two existential situations, there is still **no choice but to make worst-case contingency plans.**



The range of control is 28%. A spike in Artic methane that occurs before human sources can be cut would render the climate uncontrollable – just think about the math, not the extinctions. To date, no controls have been demonstrated even without a postulated methane crisis.

4.2.2 Risk Management

Permitting an exceedance of the unknown Artic Tipping Point Temp is not management of risk. Foreclosing the possibility of this exceedance is.

How would this foreclosure occur? The market for natural gas is well established but not well understood, given the inability to predict natural gas market valuation. The most obvious steps are no surprise.

Step 1

Perform gas infrastructure end-to-end Leak Detection and Repair (LDAR). There is no industry mandate to accomplish this (neither from regulators or civic-minded stakeholders). The only attention to this critical issue is from the US Government Accounting Office (GAO) report:

(1) Defines levels of performance and address all core program activities and
(2) Uses budget data to refine performance goals for its gas storage program.

This GAO report has been issued in response to the discovery of unreported long term methane leaks like the Sabine Pass LNG Export Plant. (Shutdown)

Extensive infrastructure repair would be necessary for certification of a leak-free gas grid. The current gas grid is too leaky to take advantage of renewable natural gas (RNG). Leaking RNG, thereby defeating its climate benefits, is categorically insane under the current methane threat. So too would be the proliferation of back yard biodigesters – they must be outlawed with severe penalties. Survivalists take note.

Step 2

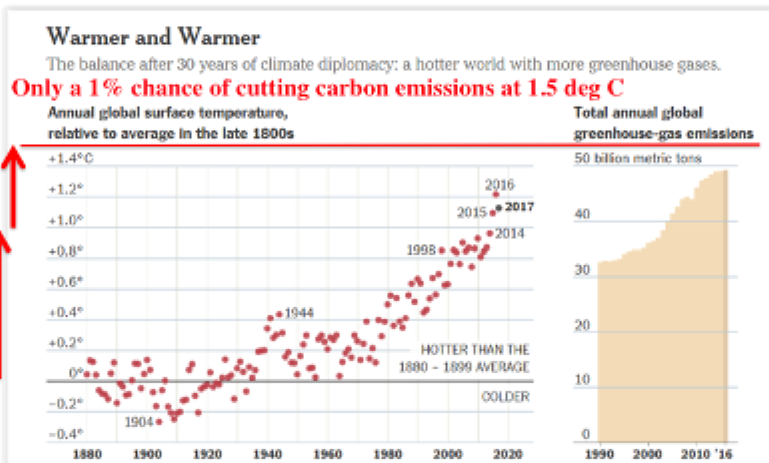
Locate and cap all abandoned gas well bores. There is no industry mandate to accomplish this (neither from regulators or civic minded-stakeholders). The number of unlocated rogue wells is astounding.

Step 3

Target a gas price that is 2x the average from the last 10 years. Start shutting down well production until this price is reached. This is a measure of market sensitivity, currently unknown, that balances market demand against the unknown Tipping Temperature margin. This is the Tillerson-Tipping pain index for possible emergency methane shutdown of all gas and oil methane sources on the planet. No one can prove that this will never be necessary. And it's possible that this could be sufficient to avoid dire consequences – if managed. BTW there has been no management, is no management, and there will be no management until beneficial authority is instituted. The proof of "no management" is abundantly evident in Figure 4.

Step 4

Biogas burning would possibly offer sustainability advantages were it not for the Artic threat, so a categorical biogas shutdown is unavoidable.



https://www.nytimes.com/2018/01/23/business/economy/fighting-climate-change.html

Figure 4 Climate policy work has had no measurable effect for 40 years

4.2.2 Risk Mitigation Math

We can understand in general terms what happens when a methane source is cut. Take a plume of methane that has been released for a day and then cut off completely. After 12 years the original plume is half what it was, because half the plume has dissipated into CO2. Another 12 years and it is down another half. At what point is it down to 1/84th of the original amount? When it has completely dissipated into CO2.

The math says for all practical purposes this takes 73 years, as depicted in Figure 5, which shows the lifetime of a single plume of CH4 released into the atmosphere. The strength of that plume declines in each subsequent year, shown as blue bars.

The next question is, if the one-day plume has dissipated, and we know this helps the planet, when does the average global temperature respond by declining to some extent? This math is less intuitive and the question probes another unknown – climate sensitivity. The best we have is a collection of models (you should believe in models – you have nothing better).

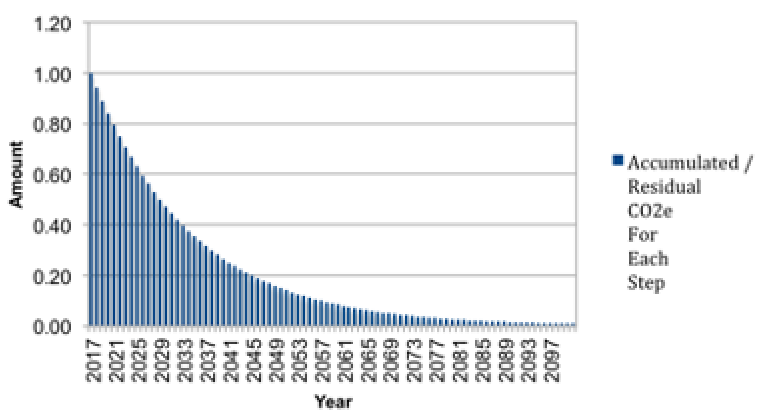


Figure 5 Lifetime of a Methane Plume

One blogger report suggested that the time for Earth to respond to increasing climate pollution is 40 years, a Climate Lag due to the heat retention of ocean waters. The lag time for cooling is no different from that for heating. From extensive modeling of this cooling delay, we now think it takes 30 years for the Earth to get better if you take away a climate-forcing factor (CO2, CH4, or some other pollutant). (Climate Lag Models). This response, though it needs more work because it is such a poorly known and survival-critical behavior, is given only approximately as shown in Figure 6.

4.2.3 Summary of Risk Mitigation Math:

1. Heat trapping capacity of a methane plume becomes extremely small in about 70 years.
2. Methane is controllable.
3. The Earth responds in 30 years if you cut all methane tomorrow.
4. Chances are that Arctic methane will tip out in the next 30 years while waiting for global average temperature to peak and start declining.
5. The longer methane is allowed to feed GHG concentrations, the more likely methane runaway will exceed anyone's ability to stop it.
6. **While we must continue to wait for any carbon sequestration technology to be demonstrated economically at scale, the only option available is to shut down all methane extraction and hope for the best.**

Even capping methane will not halt the massive carbon release every year as summarized in Figure 7.

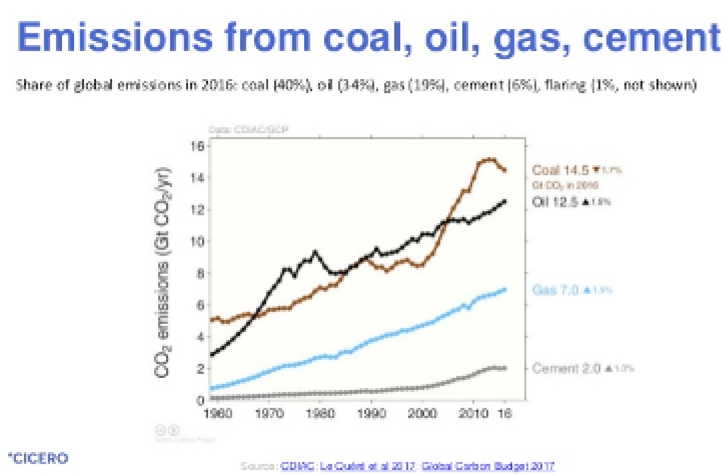


Figure 6 Total CO2 emissions increase every year

5.0 CONCLUSION

Rather than wait until we know everything about the business and economic damage posed by ongoing climate damage, while business and financial interests actively oppose any payment for their known share of damage to the planet, you can plainly see there is enough information to act decisively now.

If effective intervention is taken soon as depicted in Figure C1 it is possible to see that the eventual risks could be avoided 10 years early, even after the 30-year Climate Lag.

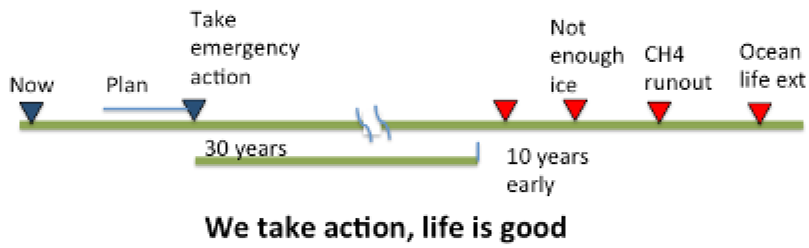


Figure 7. We Take Action, Life is Good

In Figure C2, you see the consequence of allowing the Climate Lag to make your genius, high-cost, planet saving intervention(s) arrive 10 years late. Incidentally, the listed hazards (we don't know all of them yet) can trigger each other into an unstoppable catastrophe.

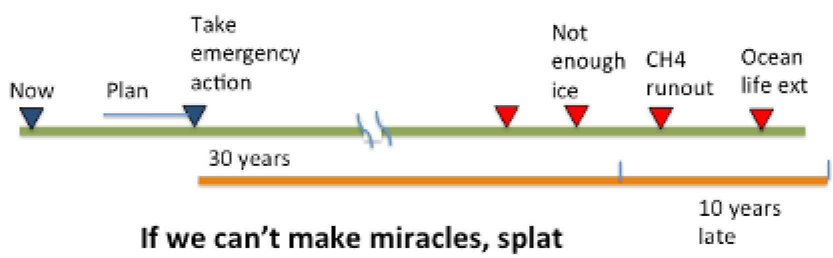


Figure 8. If we Can't Make Miracles, Splat