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The Small Book of Big Thoughts

Climate Change

Hell on Earth

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This is how we die!

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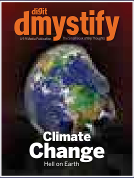
INSIDE



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You're getting warmer!

We could have called this book global warming, and we nearly did, except that we didn't want stupid people to be able to dismiss this book by pointing out a really cold winter in an otherwise warm country and say "Global warming? Bah, humbug!"

We had to call it climate change, because we have to account for such people (sadly), and we have to try and reach them to make them understand exactly how important this issue is already. Yes, climate change happens on Earth all the time, and has probably happened dozens of times (if not more) in Earth's over four billion year history. The Earth has seen ice ages and super hot phases that make today's record high temperatures look like a chilly winter, however, never before has the change been so rapid.

Is the Earth warming up on its own? Perhaps. However, temperature changes that would usually take multiples of 10,000 years are now happening in mere centuries. Imagine a guy who was struck on the head by a stupid stick, fell into a vat of 100% stupid alcohol, and then stupidly tried to light a stupid match to start a fire to dry himself off... you'd have to either be that stupid, or be a politician, to deny the proof that climate change is being accelerated at an insane pace by humans. ■

History

Last month we told you all about Earth's history, mainly through geology. We'll start off with presenting you with the evidence of climate change in our planet's distant past...

The study of the climate changes in the planet's distant past is actually called Paleoclimatology. Although this book is really about the man-made problem of climate change, it's important to understand exactly what the past of our planet was, in order to understand what the future might be.

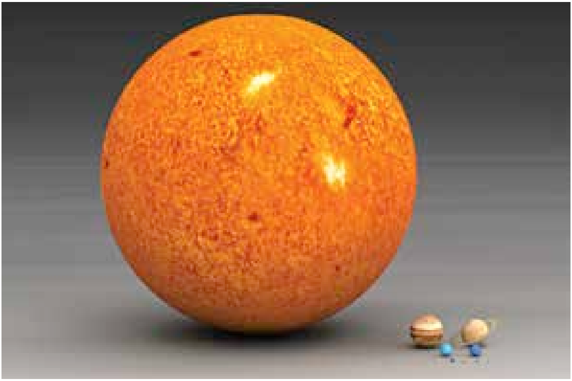
The Earth has gone through many climate cycles that were disastrous for a lot of living things, and it will in the future as well. Even if we did absolutely nothing, and stopped using all fossil fuels today, and went as green as the cavemen were, the climate will still change eventually and kill us all. However, this will happen at a time scale that's conducive to evolution, and thus the lifeforms that might exist on Earth a million years from now could be well adapted to, say, a very hot planet with a much thicker and denser carbon dioxide content in the atmosphere. This has happened before, and will happen again. Let's take a quick trip down memory-lane and understand some of the important changes in Earth's climate, and what it did to life, at the time.

First of all, it's important to understand what causes climate change here on Earth, and the factors that do, are quite simply:

- Brightness of the Sun
- Earth's orbit around the sun (distance from the sun)
- Earth's wobble and tilt
- Reflection / blocking of energy from sun before it reaches Earth's surface
- Continental drift
- Greenhouse gases

Brightness of the Sun

This one is pretty simple. Obviously, when it comes to early Earth (and also, the early sun), as a new star, the sun was still getting heated up. Over the 4.5 billion year history of the Earth, the sun has gotten progressively warmer. It's now in a somewhat stable phase that will last about 5 billion years more – so we're pretty sure the sun is not an immediate threat to us. Of course, this doesn't mean that the sun doesn't change at all, and in fact, the sun's temperatures vary, as do the amount of energy sent towards Earth, and we've all heard of things called solar flares which can up the radiation... then there's



The sun was only 70% as bright 4 billion years ago. The Earth is a tiny dot at this scale

solar activity cycles of solar maximum and solar minimum which is roughly a cycle that occurs every 11 years or so. We're currently in the 24th solar cycle – since we started measuring at about 1745 – and despite the increase in temperatures globally, we're actually in the middle of one of the weakest solar cycles in the past century. The solar cycle happens when the magnetic dipoles (north and south) of the sun flip every 11 years. This happens because the sun is made up of plasma (fourth state of matter) unlike the solid inner planets or the cold outer planets. This means that "stuff" at the sun's equator rotates a lot faster than the stuff at the poles, and this means that weird currents start acting up causing the dipoles to weaken during every cycle.

Historically, all physicists seem to agree that the sun was releasing only 70% of the energy it releases today back when the Earth was born. This means that the Earth was getting a lot less sunlight, and thus temperatures should have been a lot colder back then. Basically, the Earth should have been a ball of ice until very recently, if (and it's a big IF), the brightness of the sun was the most important parameter in deciding climate change on Earth. The geological record shows that this is not the case, with many hot and cold cycles showing up in the rock history. Thus, the brightness of the sun contributes only a minimal amount to climate change. Something else is obviously the headline act...

Earth's orbit

This one seems to be a no brainer. When the Earth is closer to the sun, it gets more heat from it than when it's further away. Assume the Earth started off early on in a near circular orbit around the sun, and thus was getting the same amount of energy all through the year. This would cause a global warming of sorts, because there would be no cold period where the Earth would move further away from the sun and thus be cooler. Of course the geological proof shows that this is actually true. Every 100,000 years the Earth's orbit changes enough to make a significant change in the climate, and the evidence seems to point to an ice age happening every 100,000 years or so.

However, calculations have shown that the greater the change in orbit, the milder the ice age that follows suit. This implies that although the eccentricity of the Earth's orbit may cause climate changes, it's not the main cause.

The eccentricity of the Earth's orbit varies from 0.0034 to 0.058 (where 0 = circular orbit). Currently the orbital eccentricity is 0.0167. As per the same cyclic measurements, we're also supposed to be in the middle of an ice age (glaciers should be growing instead of melting). The fact that the opposite is happening suggests that there's a factor that's more powerful than even the orbital eccentricity of the Earth at work here.

The wobble and tilt

We all know that the Earth is tilted a little (axial tilt) in reference to the plane of revolution around the sun. This is what causes the north pole to get 6 months of day followed by 6 months of night, while the south pole experiences the opposite. According to scientists' careful calculations, the axial tilt of the Earth is thought to change. There's also a wobble, which scientists call precession. What this means is that if you stood at the north pole, looked directly up, and kept looking at the heavens for thousands of years, you would notice that the Earth wobbles like a wobbling top, and makes one cycle of a wobble every 26,000 years.

This wobble also affects the axial tilt, which changes from a minimum of 22.1 to a maximum of 24.5 degrees in about 41,000 years. The angle of tilt is currently about 23.44 degrees, and is decreasing – it will decrease over thousands of years to to 22.1 and then start increasing again.

Now, there is evidence that links the change of climate (historical ice ages, specifically) to this as well. Because the arctic and antarctic circle grow smaller and larger as the axial tilt changes, this would result in changing climates. However, we're kind of bucking the historical trend, and getting warmer when we should be getting colder.

Reflection

This is actually like a chain reaction for growing colder, or basically what happens in an ice age. Put simply, ice is white, and white reflects the most light (and as a result, heat). This is why you feel cooler wearing a white shirt (or light coloured shirt) when standing in the sun as opposed to a black (or a dark coloured) shirt. What this means is that when more ice starts forming on the surface of Earth (as has happened in the past), the ice itself speeds up the climate change. In such a case the ice age is sped up, and the Earth stays colder for longer. This is because as

Snowball earth could have looked like this
(Image: Wikipedia | Neethis)

more of the earth gets covered in ice, more sunlight is reflected and the temperature of the climate system is lower, and more ice forms. This isn't what's happening now though, and in fact, as more ice melts, the land absorbs more energy and the system gets hotter. Basically, if human output is making the world hotter, the lack of reflection of energy at the poles will help speed up the process of global warming.

Continental drift

This is one of the contributing factors to very long term climate change. For example, when there's no land mass at the south pole (when Antarctica was part of the supercontinent Pangea, for example), it was harder for ice to form at the poles and thus the Earth was warmer (because of less reflection, amongst other factors). Another way climate change is affected is when the large portions of land are not broken up by the sea. With a larger portion of land away from the sea, the internal areas tend to become very dry (arid), and deserts form. Thus the shape of the land on a planet actually affects not just the weather, but also the climate of the planet in a big way. Of course, since continents move about as fast as a standard human hair grows, any changes to climate that continental drift does is over hundreds of thousands of years. It certainly doesn't explain the drastic changes that we've seen happen in the past century or so.

Greenhouse gases

And finally we arrive at the last significant contributor to climate change. We've saved the best for last on purpose, because almost all climatologists believe greenhouse gases such as methane and carbon dioxide cause the most drastic climate changes. Of all the greenhouse gases, it's carbon dioxide that's the most abundant and thus the most dangerous. A methane atmosphere would cause a much bigger greenhouse effect, but methane is scarce on our planet.

The early Earth (about 3.5 billion years ago) had a much higher concentration of carbon dioxide than now. Early living things (especially cyanobacteria) used photosynthesis to convert carbon dioxide and water into carbohydrates and simple sugars, and released oxygen as a by product. A lot of the oxygen that was released as waste by the cyanobacteria was absorbed by the iron that was dissolved into the oceans. Iron oxide, however, is heavy and sank to the bottom of the ocean floors. Once this happened, and the oceans started getting saturated with oxygen, it soon started leaking into the atmosphere. This was devastating to life that wasn't used to oxygen. A lot of the iron on the land masses also "rusted" as it absorbed oxygen from the atmosphere, however, eventually, the system became too overloaded, and free oxygen started accumlating in the atmosphere.

Known as the oxygen holocaust, or the great oxygen event, the largest extinction event in Earth's history happened 2.3 billion years ago. Almost all early life went extinct, except for life forms that used oxygen to survive. We should be thankful, though, because the life forms that evolved to use oxygen instead of carbon dioxide were our earliest ancestors. We wouldn't exist today if it wasn't for teeming colonies of trillions of cyanobacteria spending millions of years removing atmospheric carbon dioxide and replenishing it with oxygen.

What the removal of carbon dioxide from the atmosphere also did was end the greenhouse effect that was occurring on early Earth. This meant that temperatures would drop gradually, and eventually the Earth was transformed into a snowball. This first "ice age" is supposed to have lasted over 300 million years (2.4 to 2.1 billion years ago). Despite the fact that the sun was warming up, it's assumed that almost all of the earth's surface was covered with ice, and thus reflected most of the sun's energy.

This pattern is repeated several times again throughout history. Our previous book, "dmystify: Earth" goes a little more into detail about these extinction events. We'll just end this section by telling you that except for large meteorites striking the earth and killing life, and global volcanic activity darkening the skies of Earth and killing almost all life, the only other killer of living things is the atmosphere – usually because of the change of carbon dioxide and oxygen ratio.

You weren't there, how do you know?

We know you wouldn't make such a silly statement, but there are many who do. Usually ignorant of scientific understanding, such people can sometimes try and corner you with illogical statements, and try and undermine the scientific method by likening it to fiction. This is why it's important to understand how scientists come to the conclusions about the climate from a million or billion years ago, and what methods they use to arrive at aforementioned conclusions. There are a few basic methods that are used, and each is a science field unto itself. We're going to run through them briefly, but we encourage you to do additional reading in order to be able to reply to idiotic questions like the one at the beginning of this paragraph.

Trees

To oversimplify a very complex scientific field of study, you can think of Dendroclimatology (studying climate change using trees) as a way of looking at whether trees either flourished or barely survived in the past, and then use modern data where similar trees have shown similar growth patterns to arrive at what the climate was like in the past.

Scientists use tree rings to try and determine if the tree had a good or bad year, and this usually works out to be: a fatter ring signifies a good year of growth, while a thinner ring means the going was tough that year.

This method is good for going back hundreds of years into the past to see what the climate was like. From the tree rings, scientists are able to find out the amount of rainfall, the average temperature, etc. In order to go back thousands of years, however, they use other methods.

Going back more than a few thousand years is possible by looking at the sedimentary data, which basically yields the few instances

You can tell a lot about the climate of several hundred years ago just by looking at tree rings

where plant life was encased in sedimentary rock. We're talking about tree fossils, and things such as pollen, a few plant specimens and plankton. Based on the type of signatures embedded in the rocks, we can arrive at conclusions of the climate around the time. There's also signs of rising or falling of sea levels in rocks, changes in chemical composition (usually brought about by changing temperatures), etc.

Ice

There are ice sheets on Earth that have remained frozen for thousands of years. In fact, drilling deep into the ice on Greenland and Antarctica have yielded ice that's been frozen for as much as 800,000 years. But how does drilling up slabs of really old ice help us?

To start with, how do you even date ice? What if there was a really cold year in, say, 3000 BC and most of the ice formed then? How scientists date the ice is pretty neat actually. Just as trees get rings, we have observed that layers are formed on ice as well. As the season changes, say from summer to winter, and more snow falls, a new layer of ice is added to the existing permafrost. Changes in the thickness of layers are used to estimate the changes in temperature.

Then there's the volcanic ash content of a layer, which can be dated by geologists to local eruptions in the past, and if the ash chemically matches the lava spewed out by, say, an eruption that happened 500,000 years ago (and also appears in the ice sheet at a depth that signifies it's about 500,000 ice layers down), you have the double confirmation needed about the age of the layer.

There's also a pretty accurate method of finding out temperatures at the time the layers formed: Water is made up of mostly Hydrogen and the Oxygen-16 isotope. However, there is also some quantity of Oxygen-18 in the oceans, and since the rate of evaporation of water made up of the Oxygen-18 isotope is lower (needs a slightly higher temperature to evaporate than O-16), the more O-18 water found inside a layer of ice signifies a higher ocean temperature that year, as more O-18 water evaporated from the ocean and then fell as rain or snow on the ice sheets.

For climate change, however, nothing is more important than analysing the tiny air bubbles trapped inside the ice layers. Scientists first date the layers by using the methods we've described above, get a good estimate for the nearby ocean temperatures at the time by calculating the Oxygen-18 content of the layer, and then analyse the air content of the tiny trapped air bubbles in the ice sheet. In this way, scientists are able to get not just the average temperature of a time in the past, they're able to say with pretty good accuracy how far back in the past it was, and also measure the composition of the atmosphere at the time. The results? Lower carbon dioxide in the atmosphere means cooler average temperatures – pretty consistently, with data that goes back 800,000 years!

Plans are underway to drill and bring up ice that's been frozen for over 1.5 million years. However, resolving to times before that will have to depend on rocks and other substances and fields that deal with several millions of years of Earth-history. Climate scientists are the first to admit that accuracy reduces as we go further back in time, however, they're all pretty much in consensus about the what the data reveals about the past 600,000 years of climate change. ■

Venus and Mars

The truly smart ones don't make mistakes themselves; they learn from others'... here are some planetary scale mistakes

We will take a short detour off the planet, and look at our two closest neighbours. We do this because it's important to understand how climate change has the ability to make entire planets uninhabitable. We want to be clear and upfront about the fact that even if mankind burnt all of the coal and other fossil fuels available to us, we couldn't kickstart a runaway greenhouse effect like the one that ruined Venus. This chapter is not here to try and scare you into going green (the rest of the book aims to do that), it's merely here to get you to understand how drastic climate change can really be. The Intergovernmental Panel on Climate Change (IPCC) – a body of the United Nations that was set up to study climate change on Earth – has stated on record that a Venus-like runaway greenhouse effect "appears to have virtually no chance of being induced by anthropogenic activities." Anthropogenic means human activities.

Venus

Venus is thought to have had liquid water oceans. In the early solar system where the sun wasn't as strong, and when there was less carbon dioxide in Venus' atmosphere, many believe that Venus probably looked a lot like Earth.

With an atmosphere of mostly carbon dioxide, the atmosphere is actually much denser on Venus. Surface pressure is about 92-times that of Earth, and to experience how the Venusian atmosphere feels like on your body, you would need to dive to a depth of over 900 metres (that's almost a km) under the surface of the ocean on Earth. In fact, you'd have to go about 50 km up into the atmosphere of Venus to reach a place where you can have the same pressure as Earth does at sea level (49.5 km to be precise).

Actually, what we know about the early Earth suggest that the Earth was more like Venus is now at the beginning. We also had mostly a carbon dioxide atmosphere, and perhaps even sulfuric acid clouds (which Venus has today). On the Earth, volcanic activity is thought to have sent out a lot of sulfur into the atmosphere and also carbon dioxide. Thankfully for us, a lot of the sulfur fell to the surface and was absorbed by the land, and our oceans absorbed a lot of the carbon dioxide, which prevented us from going the way Venus did. At that same time in ancient history (about 4 billion years ago) it's thought that Venus had liquid water and perhaps even life!

As the sun grew hotter, more of Venus' oceans evaporated and formed even thicker clouds, which in turn caught a lot more infrared radiation. Water vapour and carbon dioxide are reflectors of infrared radiation that the planets emit. The surface of a planet (land or water) absorbs energy from visible light, and then radiates it out as infrared radiation. A very dense water vapour cover (or a carbon dioxide atmosphere) traps infrared radiation, and makes the planet progressively hotter.

Now, on Earth, the water vapour condenses to form clouds, which then drop rain on to the surface – the whole weather system functions based on temperatures and (high and low) pressures. This is how the Earth regulates the climate.

On Venus, however, since it is much closer to the sun, scientists believe that the oceans started boiling when the sun started getting brighter and warmer. This means that more water vapour in the air caused higher surface temperatures, which again caused even more water vapour to be in the air. This is basically how the runaway greenhouse effect on Venus got kick started.

So where's all the water now? At very high altitudes, water vapour is broken down by the sun's ultraviolet radiation, and converted to hydrogen and oxygen molecules. The oxygen that's released is highly reactive, and combines with carbon (spewed out by volcanoes and the likes) to form carbon dioxide, and with sulphur to form sulphur

Venus is an example of global warming gone bad

dioxide, and also with sulphur dioxide to form sulphur trioxide, which then reacts with water vapour to form sulfuric acid... and you get the picture. So where's all the hydrogen gone from Venus' atmosphere? Blown away by the solar wind, thanks to Venus not having a strong magnetic field (which Earth does!). Of the trace amounts of hydrogen found in the Venusian atmosphere, (most is locked up as sulfuric acid and hydrogen sulfide), the deuterium-hydrogen ratio is very high.

Deuterium is an isotope of hydrogen that's heavier, as it has a neutron in the atom — normal hydrogen (protium) has only one proton and one electron, and no neutron.

The D-H (deuterium-hydrogen) ratio on Venus is about 150-times higher than on Earth, which scientists believe is indicative that most of the hydrogen in the atmosphere was blown away with the solar wind.

On the surface on Venus, the pressure is so high, that despite being the hottest planet (462 degrees celsius on average) carbon dioxide exists as a hot liquid, and not a gas. As we mentioned before, since Earth-like atmospheric pressure is witnessed at 50 km above the surface, and since the ideal temperature for us to exist occurs about 53 km above the Venusian surface (at 52.5 to 54 km above the temperature ranges from 20 to 37 degrees celsius), there's a lot of talk about looking for life in the clouds at that altitude on Venus. This is possible because we know that single-celled life exists on Earth at very high altitudes, and can survive high pressures and also very high or very low temperatures. In fact, some feel that because of the solar wind, there may be some organic matter from Venus being blown towards us. Some extrapolate this to science fiction levels to suggest that we may all be Venusians, because early Venus was more like current Earth, while early Earth was more like current Venus... which could mean that life got started on Venus on hitched a ride to Earth on the solar wind when things went all wrong on Venus.

Another fantastic suggestion put forth is to colonise Venus by setting up colonies in its atmosphere, at about 53 km above the surface. It's perfect temperatures for humans to be comfortable, and also perfect pressure outside the ship's hulls, Plus, the fact that the atmosphere is so thick means that a balloon filled with breathable air for us would be like a hot air balloon on Earth, and that itself would keep us afloat way above the Venusian surface.

Fantastic ideas aside, Venus is still an example of how wrong climate change can be, and how devastating it can be for life. No one expects the Earth to have a runaway greenhouse effect as Venus has got, however, everyone is really aware that all complex life on this planet cannot survive Venus-like average temperatures of 462 degrees C. Heck, complex life might get wiped out if the temperature of the Earth is raised by a mere 6 degrees C on average.

What we do have to ask ourselves is whether we want to keep contributing more and more carbon dioxide into the air, and risk causing a mini greenhouse effect that could potentially kill off entire species of living things – including us.

Mars could actually use some CO_2 to make it warmer

Mars

Because we haven't been able to observe any other planet as closely as Mars (not counting Earth, obviously), we often find ourselves looking to find similarities and answers on the red planet. Mars is the only planet whose surface can be viewed from Earth with a powerful telescope. It's also been well studied across human history, and despite being smaller and much less dense than the Earth, Mars still produces some exciting climate patterns.

To start with, Mars has polar ice caps, and even has seasons. NASA recently announced that when the seasons change, there is evidence of liquid water flowing (seeping would be more accurate) on the Martian surface. It's nothing like Earth to look at, and quite different in terms of weather phenomenon, however, Mars has also had periodic ice ages, just as the Earth has.

Although there are suggestions that Mars might have had a much thicker atmosphere in its past than Earth does today, made up of carbon dioxide, recent data suggests otherwise. However, it definitely had a lot more carbon dioxide in its atmosphere than it does now, and many believe that this would have caused warming of the surface to a point where there would often be above zero degrees C zones on Mars. This would mean that liquid water could have flowed on early Mars, which would also explain the gullies found on its surface. Now, of course, it's way too frigid for liquid water to exist or flow in all but the smallest amounts (as shown by the recent NASA announcement of water seepage).

Unlike on Venus, where Hydrogen was blown away by the solar wind, on Mars it was the carbon dioxide that was blown away. Mars is now the shining example of what too little carbon dioxide in your atmosphere can do to a planet. ■

Mankind: Polluter extraordinaire

From the birth of the industrial revolution, here's a short look at some factors that contributed to the state of things today

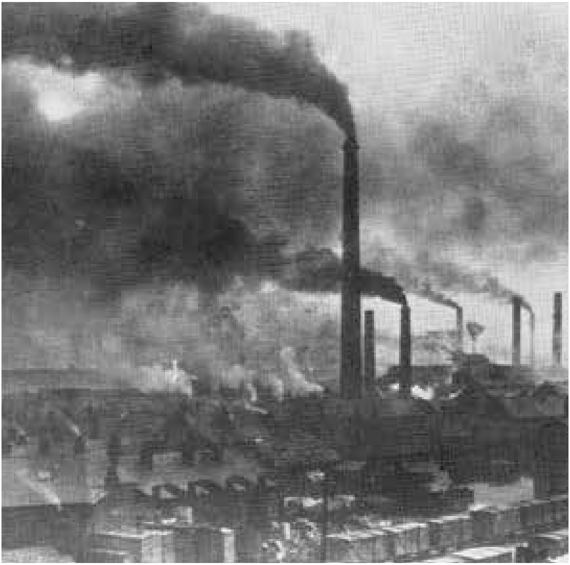
To start off with, let's first get some things straight. Why are we worried about climate change? Are we trying to save the planet? Heck no. The Earth was fine for billions of years before we got here, and will be fine billions of years after we've killed ourselves with our own stupidity.

Somehow mankind survived the very real threat of blowing itself to smithereens, only to start to cook itself slowly to death. Like frogs in water slowly being heated, eventually we will boil and die, and it will happen while we splash about playfully, without us realising it. In fact, there are global warming, or climate change deniers who we will talk about in brief later. For now, let's look at what's brought us to where we stand.

Power hungry

Let's face it, today, everyone who is reading this book is also power hungry. No, we don't mean in the same way politicians are power hungry, we mean it in terms of electricity. With each one of us having our own personal devices, and using an increased amount of technology to do work, have fun, learn, etc., our electric consumption as individuals has skyrocketed over the past decade. With gadgets in our pockets but also a desire to watch stuff on the biggest screen possible, we're sucking power like energy vampires. Growing countries such as India and China are only now hitting peak development phases, and thus they're some of the biggest power users in the world.

We're not going to mince words. For almost a century, the now developed countries such as US, UK, France, etc., went about wantonly polluting in the name of progress, and now, are trying to hold the developing countries to ridiculous standards that they couldn't have adhered to themselves in their developing phase. However, since the problem is not country specific, because mother nature doesn't care about artificial borders drawn on maps, we are going to have to swallow the bitter pill of having to play by newer rules, as science now know things we didn't before. Is it fair to us as a country? No. Are we Indians pissed off by all the rules being set by those who have already reaped the rewards of polluting carelessly?



A chemical plant in England in the late 19th century

Yes. But when you start thinking as a human being, and not as an Indian, you know it's the right call to make. Of course, whenever you meet a first-worlder, you should rub their noses in it every chance you get. Remind them how this whole climate change catastrophe is really their doing, and now we're having to clean up their mess, and succeed in developing where they would have failed… it's only a small consolation.

Industrial age

The industrial age (or the industrial revolution) was basically a 100-year period between 1770 and 1870 where humans developed machines to speed up production. It was a very significant change, as previously almost everything was made by hand by skilled people. Factories were born, and mass production started in this time – pretty much the modern way of doing things even today.

As usual, we can thank the British for bringing this new form of manufacturing to the world. The most amount of money was initially invested in textiles, as machines made much more cloth, and did a finer and quicker job. This meant that not only did quality improve for cloth, but the world was eager to adopt textile machines, and as a result, bring down the cost of clothes. Since everyone needed clothes, it makes sense that it all started with textiles.

It wasn't just cloth, however, because there was also chemical manufacturing that was now easier in the industrial age. Factories that made iron started cropping up across Europe, and the rest, as they say, is history.

Another area that took off at the end of the industrial century was steam-powered machines. Everything from steam engines to drive railways and ships, to steam powered factories. It's not just machines, but tools that also gained importance in this age. Because metal was so much in demand, and iron refineries were cropping up everywhere, people needed a way to work with metal. This meant you had to find a way to drill holes into metals, shape them, or cut strips, and do many other such tasks. Thus were born the borer machine, the industrial lathe, etc.

All of this was made possible by using coal (or coke, which is just refined carbon), to make really hot and large furnaces, which in turn made manufacturing possible. Everything from steam-power, to chemical manufacturing of iron, or even concrete was made possible by burning carbon.

Another aspect where coal contributed was gas lighting, which allowed factories to be run around the clock, because you no longer struggled in the dark with candles. Agriculture also benefitted a lot in the long run from coal power driving machines that did everything from the tilling of the land, the sowing of seeds, the harvest and even the watering of plants. It was the agricultural revolution which when crossed with the industrial revolution made it a lot easier for farmers to hire less humans to do the same amount of work, food became cheaper, and there were more people available to work in different areas, which resulted in a lot of technological development.

Of course, no one thought about pollution, or carbon dioxide, or greenhouse gasses back then... well a few scientists might have, but no one took them seriously.

Svante Arrhenius, a Swedish scientist, in 1896 told the world that burning fossil fuels could result in global warming, because of the greenhouse effect. Of course, he was ignored back then because it was believed that the oceans would absorb any extra carbon dioxide that humans could put out. This has since been proven to be a false assumption, and it's calculated that only about one third of human produced carbon dioxide is absorbed by the oceans.

From the 1940s to the 1950s, infrared spectroscopy gained prominence, it was used to show that increasing carbon dioxide in the atmosphere did actually result in trapping more heat. Also, carbon dioxide was catching heat that water vapour otherwise wouldn't.

New research into ocean sedimentary rock showed that there had been at least 32 cycles between cold and hot spells of climate change. Then there was research that showed that average temperatures were actually reducing slightly, and this sparked a global fear about entering a new ice age. People were actually fearing global cooling back then.

When in the 1980s, research showed that temperatures were actually rising, and more rapidly than ever before in known history, or even estimated history of the planet by paleoclimatologists, that's when real concern for global warming started.

Since then, there's been a lot of back-and-forth about climate change, and many scientists (usually not climatologists) have famously tried to debunk climate change as something made up by those with wild imaginations. Sometimes it is out of genuine ignorance, and sometimes it is malicious, because the scientists who try and debunk global warming are often on the payroll of oil and natural gas corporations – the companies that have the most to lose from regulations of carbon dioxide emissions.

However, it's since become a lot clearer that there is indeed global warming happening, and the Earth is warming rapidly.

In denial

As with almost everything that humans do, there are always those who will counter it. We see this all around us in the form of conspiracy theories about almost everything. Science seems to be a particularly ripe target, perhaps because it is the most misunderstood by the general public.

An example are the anti-vaccine activists who try and sabotage the work done by governments to try and eradicate disease, and instead host disease parties, encouraging other anti-vaccine families to come and contract a disease. Thus some people hold pox parties, in which perfectly healthy kids are exposed to one child with chickenpox, and fall sick, in an attempt to build up their immunity. The insanity has progressed to a point where anti-vaccinationists are online asking people to post them items that have been used by a sick child, so that they can infect their own child – presumably because they have no other anti-vaccinationist friends living nearby. This is despite the fact that sending a disease deliberately through post is illegal in the US, and many doctors have made public statements and appeals against this, because the flu, measles and chickenpox germs aren't able to survive for long when exposed to air anyway. However, what the parents could be exposing their child to could be potentially deadly diseases such as Hepatitis B, which can survive for long enough to get mailed across.

Of course, such examples can be brushed away as rare, and unimportant. Some would go as far as using the theory of natural selection to say "Let them clean their own genes out from the genepool by killing themselves". The problem is that these kids are still sent to normal schools, where they might infect other kids, and potentially start a pandemic.

Now it's all very well and good for a few crackpots to try and take down science, which we know is not going to affect policy, because

Ivar Giaever, Nobel Laureate, and climate pseudoscientist (some would say)

no law maker is going to enact a law to please anti-vaccinationists, but sometimes the trolls can be scientists themselves.

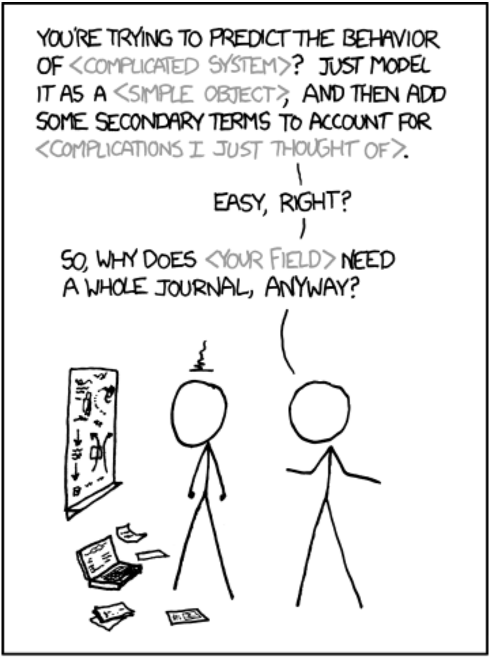
Coming back to the topic at hand, there have been many climate change deniers over the past few years, and some of them have actually done some good, as they've forced climatologists to find newer and more accurate ways of gathering data, in order to answer the questions that were raised. However, sometimes, it's just a case of ignorant arrogance, or malicious intent, based on greed. We cannot delve too deep into this because this book is too small to carefully and neutrally cover all aspects of this supposed disagreement of climate change.

However, we will take the most famous example that's often cited by climate change deniers, and present both sides of the argument, and leave the final decision for you to make:

There's a famous video that's done the rounds of the climate change debate. It's a video of Ivar Giaever, a Norwegian Physicist who shared the Nobel prize in Physics in 1973 for quantum tunnelling in solids (Giaever's specialty was tunnelling in superconductors). In the video, Giaever is addressing a meeting of Nobel laureates, strangely abandoning his specialty and focussing on climate change. You can watch the video here: *http://dgit.in/GlobWarmHoax*

There's a rebuttal of the video as well that we'd like you to read. That rebuttal is located here: *http://dgit.in/IvarRebuttal* – as usual, the arguments made in the comments section on that page are more fun to read than the actual rebuttal itself.

To sum up the rebuttal, as the site did itself, we present you with an xkcd.com comic that says pretty much everything that can be said about this particular topic. (see next page)



LIBERAL-ARTS MAJORS MAY BE ANNOYING SOMETIMES, BUT THERE'S *NOTHING* MORE OBNOXIOUS THAN A PHYSICIST FIRST ENCOUNTERING A NEW SUBJECT.

From: **xkcd.com** – our favourite geek comic

Even Nobel laureates are fallible, especially when the data they're relying on is gained by "googling" for about an hour and a half. So should you blindly accept all that scientists say (peer-reviewed papers, of course) about things in their own field of study? Yes. You should totally take Ivar Giaever's word on quantum tunnelling in superconductors. Isn't that like a "religion"? No, because this is based on evidence and peer-review, as is the scientific method, and it has nothing to do with belief. It has everything to do with evidence and testing of theories with scientific methodology of repeatability.

Some would equate pseudoscientists to that irritating person in the crowd at a cricket match, who sits in the cheap seats, shouting advice at, say, Sachin Tendulkar, telling him what shot he should have played. Such people use cricketing terms that they picked up from hearing commentators talk, mix it with a dash of some gyaan they have googled, and then season with a large helping of narcissism, to somehow convince themselves that they're more qualified than an expert, to the point where they're unafraid to even claim that in public!

Don't get us wrong, such people are an awful amount of fun, and usually good entertainment, but you shouldn't really be learning anything from them. In fact you should request them to move to the wilderness so that they can host their pox parties in peace without infecting the rest of us with their stupidity. ■

Alternative energy

The holy grail of science... the richest corporation that mankind has ever seen might be the one who invents cheap, clean and green energy

If there's one thing that's always irritated us at Digit over the years, it's been battery technology. We're known to be awfully frustrated by batteries and them not keeping up with demands. The exact same thing is happening with energy globally. We're too reliant on fossil fuels, and regardless of whether or not this will lead to irreversible climate change that may or may not make a lot of species extinct, to put all your eggs in one basket is never a good idea. Let's forget the world for a minute, and focus on, say, India.

Recently there was news of a setback in terms of solar power for India, where the world trade organisation upheld a US demand that prohibited India from banning or highly taxing US companies wanting to sell their solar power products in India. What India wanted to do was to encourage the setting up of a local solar power industry, which is still at a nascent stage of development. Obviously, local players could not compete with established foreign players. However in order to build expertise and an industry around it, hands on experience in all aspects of solar power was needed. You would think that the world's largest polluter in the history of mankind would support such an initiative by India to try and go green, but the opposite is what happened because the solar power lobby in the US stood up and screamed about capitalism being their right. Basically, greed won over trying to save the planet.

It's politics and setback like this that will continue to hinder the fight against global warming. However, you shouldn't shun solar power just because it's made in the US and not in India. We encourage you to do research and buy only made in India products, even if it means paying a little extra, because it will go towards supporting local businesses. If you can afford it, however, you really should be getting some solar panels set up. Let's take a look at the alternatives to fossil fuels, and even ways of making fossil fuels more efficient, so as to reduce the amount of carbon dioxide we put into the atmosphere.

Solar

This one's a no brainer. By far the most abundant energy source on planet Earth is sunlight. We get a heck of a lot of it, and it's really the energy that's causing global warming anyway. Greenhouse

Harnessing the power of the sun

gasses may help make things warmer, but the largest source of energy is the sun. It would make sense, then, to have as much sun fall on solar panels as possible, so that we can harness the energy of the sun. Better than it being absorbed by the ground and then radiated back into the atmosphere, which traps it and makes the whole world hotter.

We have all heard of solar power, but how does it work?

Solar panels are nothing more than a large array of photovoltaic cells, which are basically cells that react to light (photons) by giving off some electrons. How does this happen? Two layers of silicon are placed really close to one another and both layers are treated differently to add other elements in order to make the layers positively and negatively charged.

First, some basic chemistry. Silicon has a nucleus surrounded by three electron shells. The first shell has two electrons, the second has eight electrons and the third has four electrons. The outermost shell is the amount of valence electrons, and thus silicon has four valence electrons. Even carbon has four valence electrons, and this means that both silicon and carbon have four electrons available to interact with other elements to form stable compounds.

Valence or Valency of an element is defined as how many hydrogen atoms one atom of an element will combine with to form a hydride, or twice the number of oxygen atoms in the element's oxide compound per atom. So, since we know that CO_2 basically has two oxygen atoms per carbon atom, the valence of carbon is 2 x 2 = 4. The same for silicon. Since Oxygen has a valence of 2, and is stable by either gaining or losing 2 electrons, it has a valence of -2, +2. Which is why elemental oxygen is usually found as O_2 in nature.

The first electron shell of elements are filled with two electrons, thus Helium is a noble gas because it has only one electron shell and that shell is totally filled with two electrons. Neon has two shells, filled totally with two electrons in the first shell and eight electrons in the second. This makes Neon a noble gas that's unreactive with other elements.

Now, let's take another example, of say, Boron. Boron has a valence of -3, +3 because it has five electrons in two shells – two electrons filling the first shell and three electrons in the second shell. Thus, in chemical compounds, boron will try to give away three electrons to attain stability, or gain three. The hydride is BH_3 (or B_2H_6) and oxide is B_2O_3. Similarly, Phosphorus has a valence of 3 or 5.

If you take a layer of silicon, which is usually rows of silicon atoms sharing the valence electrons amongst themselves to be stable, and then inject boron atoms in between silicon atoms, you basically get a electron shortage. Since boron has only 3 valence electrons, everywhere a boron atom is next to a silicon atom, you get a shortage of one electron to complete the stable configuration of 8 shared valence electrons. This gives this particular layer of silicon a slightly positive charge. The next layer is treated similarly, however phosphorus is added instead, which basically means that you now have an electron to spare. At every place where a phosphorus atom sits next to a silicon one, you get one extra electron that is just itching to get the heck out of there.

When a photon comes along and excites this spare electron, it gets knocked out of the phosphorous atom and is transmitted to the metal side of the photovoltaic cell. It is then transmitted to the wire that connects the metal shells of the cells, which then makes it just simple electric current. It's then transmitted to a battery where the charge is stored. The circuit is completed with the other positive layer of silicon connected to make up the electric potential difference.

Remember, this is an oversimplified explanation, and in practicality many different compounds are used, and there are different ways in which the circuit is set up, with electrolytes separating the two layers, to keep replenishing electrons back to the negative layer of silicon, but the principle of functioning is pretty much the same.

Wind

Many people believe this is also really solar energy, as the wind is really driven by the heating of one half of earth by the sun while the other is cold, and also uneven heating because of differences in terrain (land, water, ice, trees, desert, etc) resulting in high and low pressure zones in the atmosphere which causes the wind.

Wind energy is really easy, because it's the opposite of how a fan works. Again, to oversimplify, with your electric fan at home, electricity is used to rotate a charged coil inside an electromagnetic

A wind farm in the Philippines

field. Using Lorentz law, and Fleming's left hand rule, we know that current flowing in a magnetic field causes the wire to experience a force, and this force is used to rotate the fan blades, which then move air, which cools you down. Windmills are the exact opposite of this. Wind moves the fan, the fan blades move the coil in a magnetic field and electric charge is formed which is then used to power whatever you want it to.

Nuclear

Basically, we use nuclear reactors to have controlled fission (as opposed to uncontrolled fission which results in a nuclear bomb). This controlled fission generates a lot of heat *(refer to our $e=mc^2$ and nuclear weapons dmystifys to understand this better)*, which is turn is used to heat up water and make steam, which then is used to pressurize and run turbines that produce electricity.

Yes, for those of you thinking it, the modern age of nuclear energy is nothing more than a return to much bigger and badder steam powered machines.

Currently, about 11% of the world's energy demands is met by nuclear reactors. Only 56 countries are currently running nuclear reactors, and a few of them depend heavily on them. France is by far the most nuclear reactor dependent country, as nuclear power accounts for about 75% of their power requirements. India is a lot lower on this list, as our 21 reactors account for a mere 3.5% of our power requirements. We are working on thorium reactors, however, and we have a huge stash of thorium to be able to depend much more on it once we perfect the technology. Only Australia, US and Turkey have more thorium than India.

Kudankulam nuclear power plant in Tamil Nadu

Since we're throwing out stats in this segment, you should know that of all the electricity generated in the world, nuclear currently only accounts for 11%, coal is used to generate about 40%, 22.5% comes from gas (fossil fuels totalling a whopping 62.5%), 16.5% from hydroelectric power (dams), under 3% for both solar and wind, and then "others" account for about 7%.

Hydroelectric

Currently the closest competitor to fossil fuels such as coal and gas, hydroelectric generation has been around for quite a long time. Over 150 countries generate hydroelectricity, and it's by far the most flexible power source. Because the flow of water can be controlled in a dam, hydro-electric power is pretty easy to scale down when the requirement is less. It's also the cheapest way to get electricity. Although it involves a large initial investment to build the dam, the cost of running it works out very cheap.

There are often environmental concerns to building dams, which usually displaces a large amount of wildlife, and also humans, and changes the ecology of a large area. You can't suddenly interrupt a river's flow and not affect the environment.

Of course, because it is the cheapest way of generating electricity, it's understandable why almost all big rivers have some form of hydroelectric power being generated from them.

Three Gorges Dam: The world's largest hydroelectric dam

There's also tidal power plants to be considered. Although not as much in use as it should be, tidal power is being looked at seriously as a way to harness totally natural tidal energy because tides are much more predictable than solar or wind, because no matter if the air is still or there's thick cloud cover, the tide will still pretty much always come in and go out with pretty decent levels of predictability. Along with nuclear, and solar power, there's a lot of excitement about harnessing tidal energy in particular.

Geothermal

The basic principle we know as geothermal energy is caused because of the temperature difference between the hot core of the earth and it's relatively much cooler surface. This causes heat to flow upwards towards the surface in the form of lava or steam. For centuries humans have used geothermal energy. The ancient Greeks and Romans used hot springs (the earth pumps hot water out of the ground in some places) to construct baths and also used the heat to warm their living spaces. In China, there is evidence of a hot spring bath dating back to around 300 BC.

Such power plants are really easy to sustain, and although some greenhouse gasses are released by drilling deep into the Earth's crust, they're negligible compared to power generation by fossil fuels – on a per unit of power basis geothermal is way cleaner than fossil fuels.

There are a few problems, because finding the right spots to build a plant accounts for a lot of the associated costs. Ideal spots are the edges of tectonic plates, where gaps and cracks in between plates cause a lot of heat to escape from the core to the surface. This in turn heats groundwater, which is super-hot but highly pressurised under the Earth's surface, and drilling into a reservoir releases the water as steam. Since there's a pressure exerted, the same pressure is used to run a turbine which produces electricity.

Although the Earth as a whole is not at risk of running short of core heat (at least not on any timescale we would ever have to worry about), there are local problems associated with geothermal plants lowering the groundwater levels, and basically pressure being reduced over time. This is also easily solved by pumping more water underground, which requires less power than is generated, and thus geothermal plants can (in theory) be self sustaining and last forever. Of course this isn't the case, and eventually plate tectonics and a shifting crust will throw some spanners into the works. However, it certainly is a method worth exploring in more detail. Currently China and the US produces the most geothermal electricity, by far.

Efficiency

Now this is perhaps the area where we really need to spend more time. As you've read before this, we're pretty much tapping into all the alternative resources for fossil fuels already. What we can also do is increase the efficiency of not just these methods, but also the burning of fossil fuels as well.

There really are two ways in which to become more efficient when it comes to fossil fuels. One is to reduce the carbon footprint of the extraction method, and the other is to increase efficiency of burning of the fossil fuel.

A simple way to understand how we can improve efficiency of burning fossil fuels is to imagine increasing the efficiency of a car. If you can extract double the kilometer per litre value from your car, you've halved the amount of carbon that's being spewed out per litre. This will obviously not happen with the same car, but you can achieve this by changing your car, getting a hybrid, or by opting for a less power hungry car – for example, settling for a hatchback instead of riding in a big SUV all alone.

That's not the only way, you can also start using public transport, or just travelling less. One way to achieve carbon efficiency is to allow employees to work remotely from home. This means there are less people travelling to and from work, and it introduces more efficiency into the system. Another way to do this in a congested city is to relax norms of heights of buildings, in order to open up more real estate. This means that more people are able to live closer to a business district of the city, and thus travel a shorter distance to work, which also helps reduce the amount of carbon dioxide that's released into the atmosphere because of fossil fuels being burnt.

You could also make buildings more efficient by designing them to use natural light better, which would mean less electric lighting has to be used during the day, which cuts down on consumption, and thus saves fossil fuels. We could also ensure that buildings are designed to be thermally efficient – to make it easier for the building to stay cool in a hot country or warm in a cold country.

The second method would be to increase efficiency at the source of extraction, and even at the power plants. If we were able to use new technologies to treat coal so that it burnt more efficiently, and also upgraded existing coal plants to be more efficient, we could drastically cut down on the amount of fossil fuel we burn to get the same amount of energy as we do today.

There are many such methods being researched and even tested, one of which includes taking the carbon dioxide that's released when natural gas is mined from below the Earth's surface, and pumping it back under the surface some distance away. Such a method traps the carbon dioxide under the Earth's crust (where it came from anyway) and makes a gas mine much more efficient in terms of carbon pollution. It's estimated that we could save billions of tons of carbon dioxide being released into the atmosphere just by adopting many of these methods, which to be honest, seem like no-brainers to most anyway. ■

Carbon math

A simple math problem, which we need to solve, or die trying

One problem we face when trying to stop any more damage to our environment is that the task seems too daunting.

When you look at the growing population, the need to bring electricity to all of the poor people in the world, lift them out of poverty and connect them to very basic technology – lights, fans, water purifiers, refrigerators, etc., you start to realise that the electricity consumption of the world is going to skyrocket. In fact, it's projected that in the next 50 years, the carbon emissions of the world are going to double, as the energy need is going to double.

One way to stem the flow of carbon dioxide into the environment was to stop adding any more carbon dioxide than we already do today, for the next 50 years. Obviously, this means that we need to provide the additional demand of energy to the world, but we need to do it with today's carbon emissions. Impossible? Let's see.

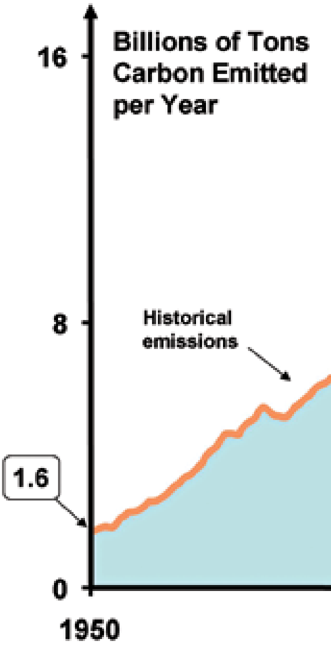
The Earth's atmosphere contains about 800 billion tons of carbon dioxide, in total, today. We burn fossil fuels and add about 8 billion tons of carbon every year. Of this 8 billion tons, the oceans absorb about 2 billion tons, and the plants eat up about 2 billion tons. This is a system that works, and we really have no idea about what will happen in 2060 when the output of carbon dioxide because of fossil fuels doubles to 16 billion tons a year. The ratio might stay the same, and the oceans may absorb 4 billion tons instead of the 2 billion it does today, and the plants might get fat by eating up double of what they do today... however, if you're rational and think clearly, you know that tree covers are reducing as deforestation is a global scourge. Increased temperatures and drier summers mean a lot of plants are being lost to fires – Australia in particular suffers from this. The oceans might only be absorbing 2 billion tons because that's the capacity. Thus, it's a very real possibility that we might end up contributing 12 billion tons of carbon dioxide to the atmosphere in 2066.

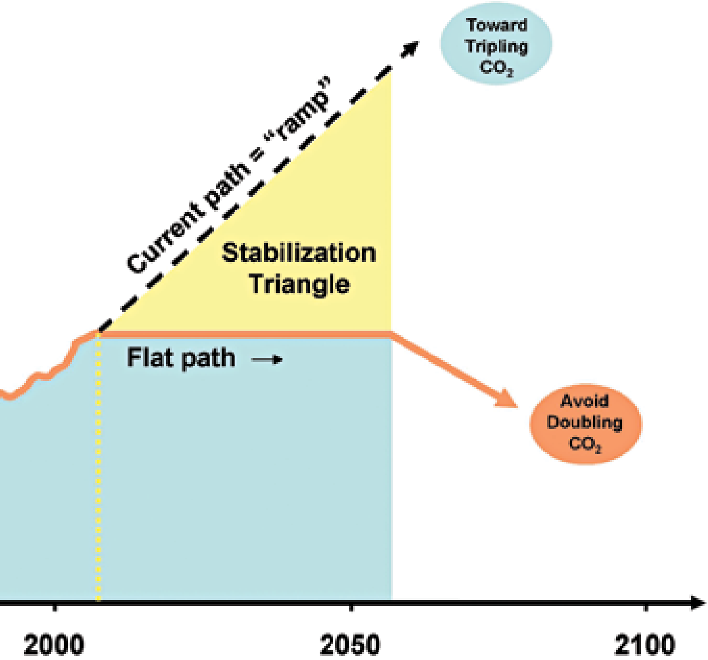
The smart thing to do is to keep our carbon emissions to 8 billion tons (and lower if possible). This means that we need to figure out methods that will cut carbon emission by at least 8 billion tons per year by 2066.

We can tell you that there's no magic technique available today that will cleanly generate enough energy to avoid 8 billion tons of CO_2. To be more precise, there's no one technique that can do that, but there are several that can be used to solve a part of the problem.

The wedges game

Stephen Pacala and Robert Socolow were working on this problem together. They knew that the way forward was not to try and find one 8 billion ton gorilla of a solution, but to put together an army of solutions that together could solve the 8 billion ton problem at hand. Of course, there was no one way to solve the

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problem, because there were many options available. Instead of trying to use complex math and try too many different combinations they wanted to break the problem down into simpler chunks that mankind could then focus on solving.

Pacala, who happens to love working with wood, hit upon the idea of making the problem into a game, and thus was born the wedges game.

Take a look at the carbon emissions (including projected emissions) (image on previous page).

From the image you can see that over the next 50 years we need to cut out about 8 billion tons of carbon emissions per year. What this translates to is cutting out about 200 billion tons of carbon emissions from today until 2066.

The yellow triangle called the "Stabilization Triangle" is the bit we really need to worry about. If we cut that bit out, that's the 200 billion tons more that we will add in the next 50 years. It's not ideal, because this solution will still ensure that we add 4 billion tons per year to the atmosphere, so ideally we should be looking to decrease the amount of carbon we emit to ensure we're not polluting the atmosphere at all. However, the Princeton duo are being realistic here, aiming at least to stem the increase in pollution before worrying about how to reduce it.

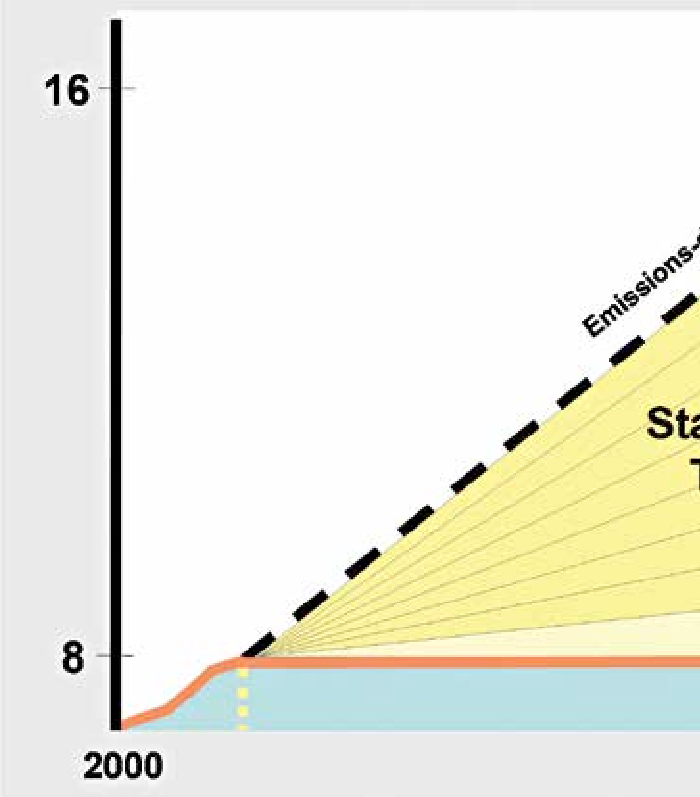
Pacala divided this Stabilization Triangle into 8 "wedges", where each wedge signified 1 billion tons of carbon per year that we will otherwise be polluting the earth with 50 years from now. (Image on next page).

He then divided up the solutions in four categories and gave each category a different colour. The four categories are: Efficiency and Conservation (Yellow), Renewables and Biostorage (Green), Nuclear Energy (Red) and Fossil-fuel Strategies (Blue). Now you can try and mix and match solutions by placing wedges into the eight available slots. You could place all red wedges, and say you want to solve the entire problem with nuclear energy, but that's not practical.

You can download the PDF of the wedges game from here: *http://dgit.in/GameboardPDF*

A description of the various strategies already available to us is listed here: *http://dgit.in/TeachGuidePDF*

Have fun playing the wedges game, and remember to send us pictures of the solutions you come up with (*editor@digit.in*). The game makes for a great group project if you happen to be in school or college still, and also makes for some interesting and informative discussions if you're an adult who's having a get together at home. ■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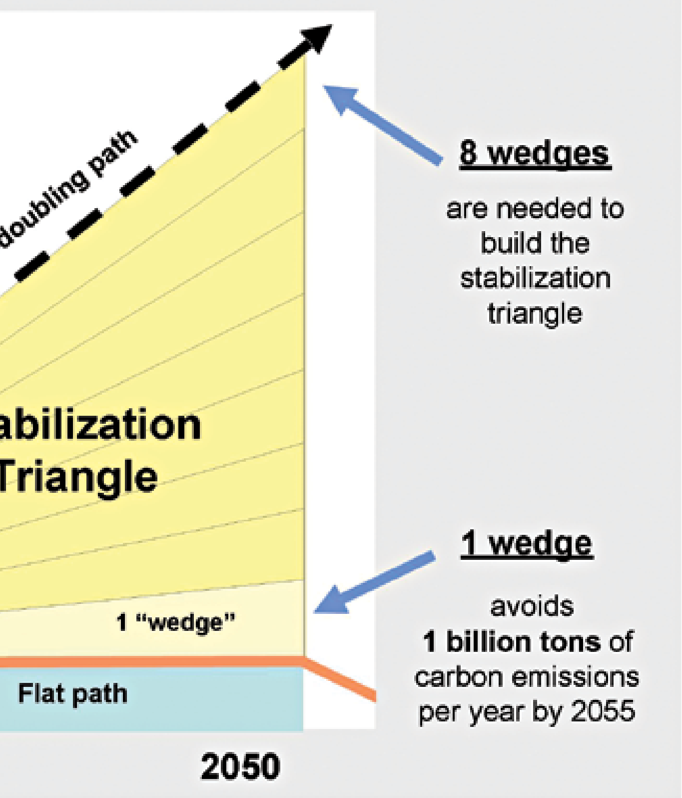
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