Sustainability

Lecture 25 – Emissions and Sustainability Considerations

http://www.thisisclimatechange.org/extreme-weather/

When you have a chance, please visit the attached link and read about extreme weather events. These weather events and their increase in occurrence is being noticed by researchers and especially insurance companies worldwide. They are yet another indicator that the climate is changing relative to what it has been like for the last few thousand years.

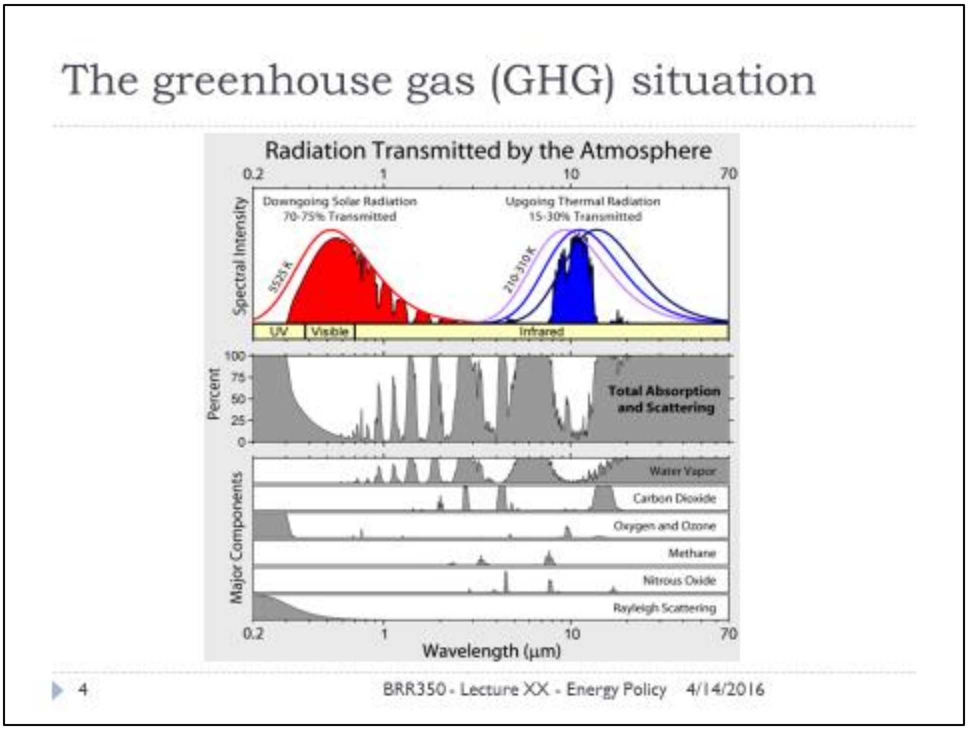
Week 10 – Sustainability
-Learning Objectives-

- Compare and contrast sustainability for fossil fuels and bioenergy, explaining how both fossil fuels and bioenergy could be sustainable and how both can be unsustainable.
- Analyze your town and describe a bioenergy process that could be used there effectively and why.

The word sustainability is derived from the word "sustain" which can mean to "maintain", "support" or "endure". For quite some time now sustainability has been used more in the sense of human sustainability on planet Earth, with a very commonly quoted definition being, "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

When we talk about sustainability we are not talking about reinventing the wheel, we are talking about improving and advancing our technology and developments so that our collective effects on Earth are less, allowing humanity to continue to survive along with the other living things on Earth. Being sustainable is about limiting your impact by using less energy, using every resource you need smarter and more efficiently, and preferably using and recycling resources that are in close proximity. Bioenergy has the potential to be a very helpful sustainable technology.

One of the big drivers for sustainability is climate change. Earth's climate effects all of us and we recently figured out that we are probably effecting Earth's climate. If climate change gets too out of hand, future generations will probably be in a lot of trouble and we will all have contributed. Given how short human lives are, it's hard to comprehend what life might be like in 200 years, but that is what sustainability demands.



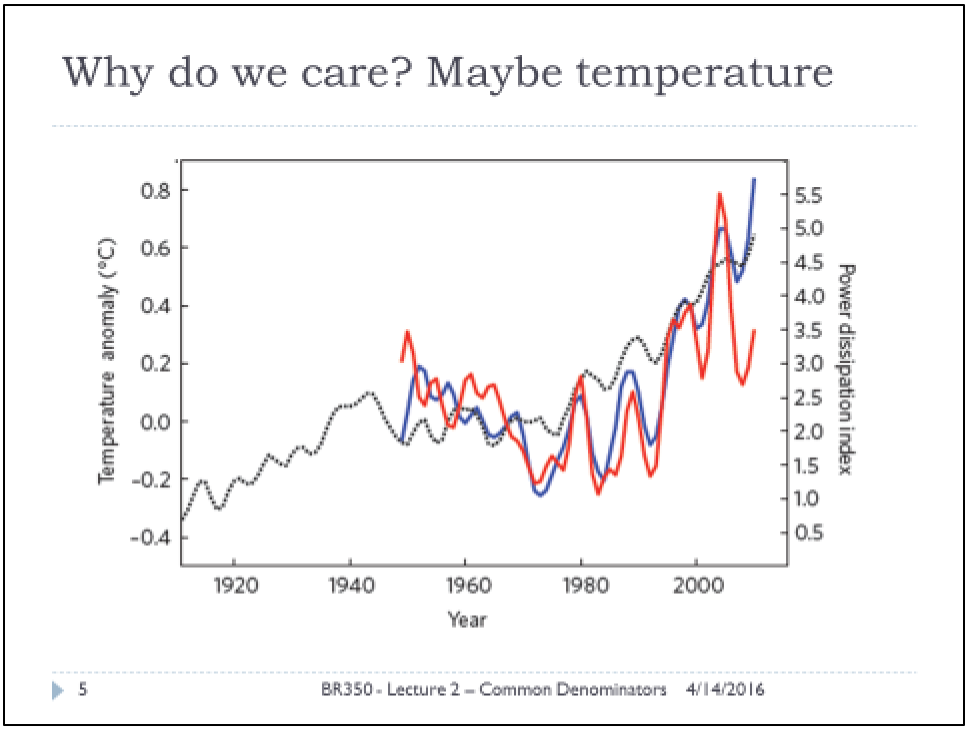
http://en.wikipedia.org/wiki/Greenhouse_gas

There is a lot of discussion regarding greenhouse gases, but very little explanation about the big picture. Basically these gases accumulate in the atmosphere and then insulate the earth. Almost nothing stops solar radiation or deep Earth heating, so the Earth is always being warmed up. Under ideal circumstances this heating is counterbalanced by cooling and the emission of thermal radiation from earth as infrared. This image does a pretty good job of showing which gases are primarily responsible for holding the heat in.

The number one greenhouse gas is water which shouldn't surprise you because when you look at the sky you see clouds. You don't see any of the other gases, but you do see the clouds and you may also realize that its warmer at night when there are clouds. Water vapor holds around 80% of the thermal energy of the atmosphere and it is a remarkably efficient heat sponge, so as it gets hotter and more humid, more heat will be held close to the surface of the earth. We honestly don't understand the upper atmosphere water vapor cycles very well, but we do know water vapor levels respond to and amplify the effects of the other greenhouse gases like CO_2, methane, and nitrous oxide.

The next major greenhouse gas is CO_2 which is why it is discussed so often. Unlike water vapor, we have had great success in tracking CO_2 levels and relating them to other Earth scale events. If you exclude water vapor, CO_2 is responsible for something on the order of 70-75% of measured greenhouse gas effects. A big part of this has to do with the massive levels of CO_2 compared to the other greenhouse gases because other prominent gases like methane and nitrous oxides are actually far better insulators than CO_2. Methane is 72x better and NO_x is 290x better than CO_2 at insulating Earth. Fluorinated gases like the ones used in our refrigerators and AC units are even worse and can be thousands of times better than CO_2.

To assess these differences between gases, a quantitative measurement called global warming potential (GWP) was designed. This is based on how much heat a gas can contain based on its mass. So a 1lb of CH_4 can hold as much heat as around 21 lbs. of CO_2. Fluorinated gases such as sulfur hexafluoride have very high GWPs because they stay around in the atmosphere forever (for thousands of years) and absorb a heck of a lot of heat.

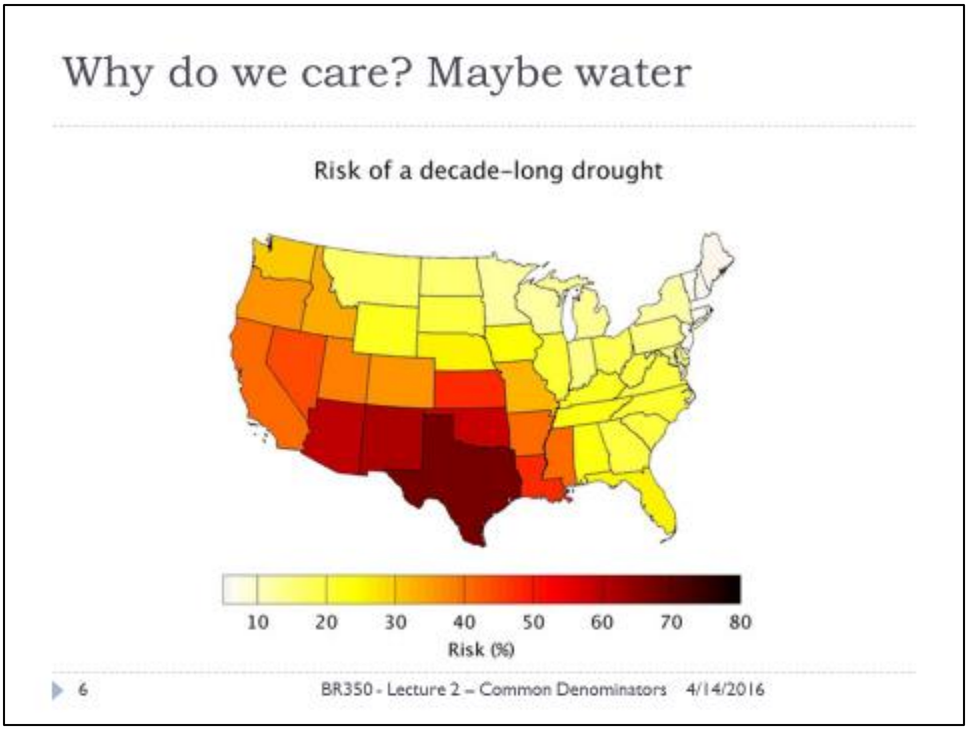


Coumou, Dim, and Stefan Rahmstorf. "A decade of weather extremes." Nature Climate Change 2.7 (2012): 491-496.

This graph from the listed paper shows the North Atlantic tropical storms in red. The tropical Atlantic ocean surface temperature is in blue, and the evolution of Northern Hemisphere mean temperature in a black dotted line. They appear to be syncing fairly well and suggest strongly that increased temperatures mean more storms, floods, and droughts.

Global warming was never a good way to describe what has been happening because the earth is a dynamic heat engine and when something gets hot, something else gets cold. It was always climate change and more to the point, just like boiling water on the stove, when things get warm they tend to have more energy to mix and on earth when large masses of water or air mix we get storms. There is abundant evidence that in the last 100 years we have seen a dramatic increase in the number of extreme weather events. This almost certainly has to do with the level of available energy in the atmosphere and the oceans being higher than it has been in the past due to fluctuations in what we refer to as GHG's. These GHG's exist with or without humanity, but we are absolutely contributing, we just aren't entirely sure how much.

From a sustainability perspective, one of the reasons we care is because we as humanity don't want to be contributing to temperature changes if we can help it. There is every reason to believe some level of climate change would probably be occurring without us, but we do ourselves no favors if we ignore our contributions to the process and potentially make it more dramatic. Life on Earth is easier for us when conditions are stable, so if we can do what humans do without making things more unstable we will generally be better off. Make no mistake, Earth has been through worse and life on earth will continue, but if we aren't careful it might continue with a lot less humanity.

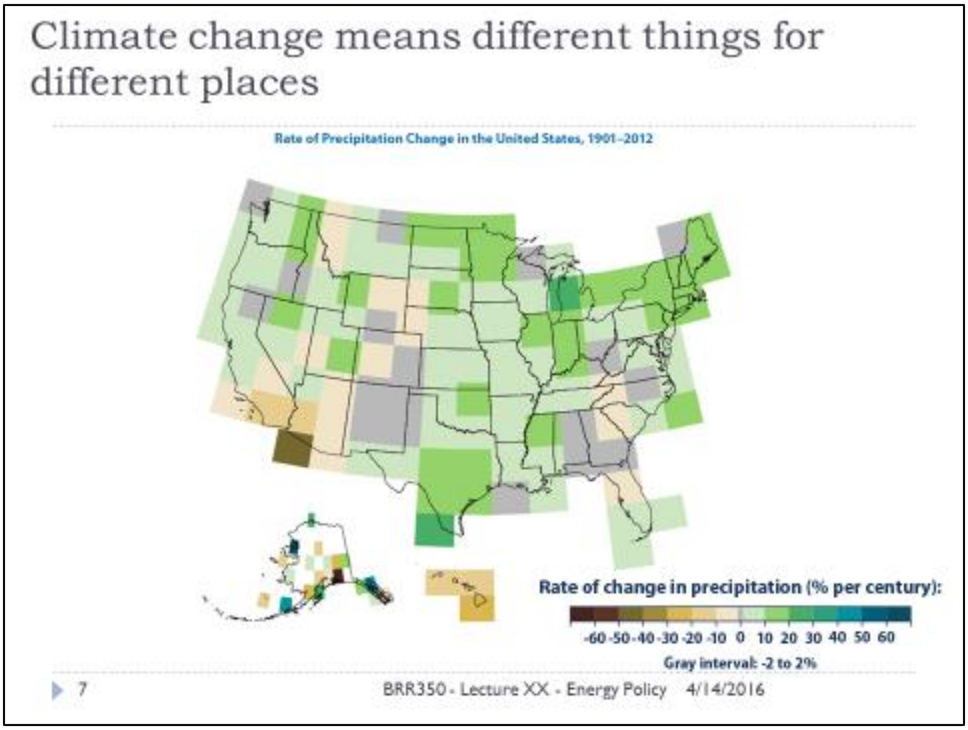


Ault, Toby R., et al. "Assessing the risk of persistent drought using climate model simulations and paleo climate data." Journal of Climate 2014 (2014).

Another good reason for caring about sustainability is water. As temperatures in the northern hemisphere creep up and as the effects of our massive scale agriculture, coal, and oil catch up with us, we are going to be facing some very serious water shortages. Imagine if Texas, Arizona, and New Mexico ended up being in a drought for 20-30 years? This would certainly change how we do things in those areas.

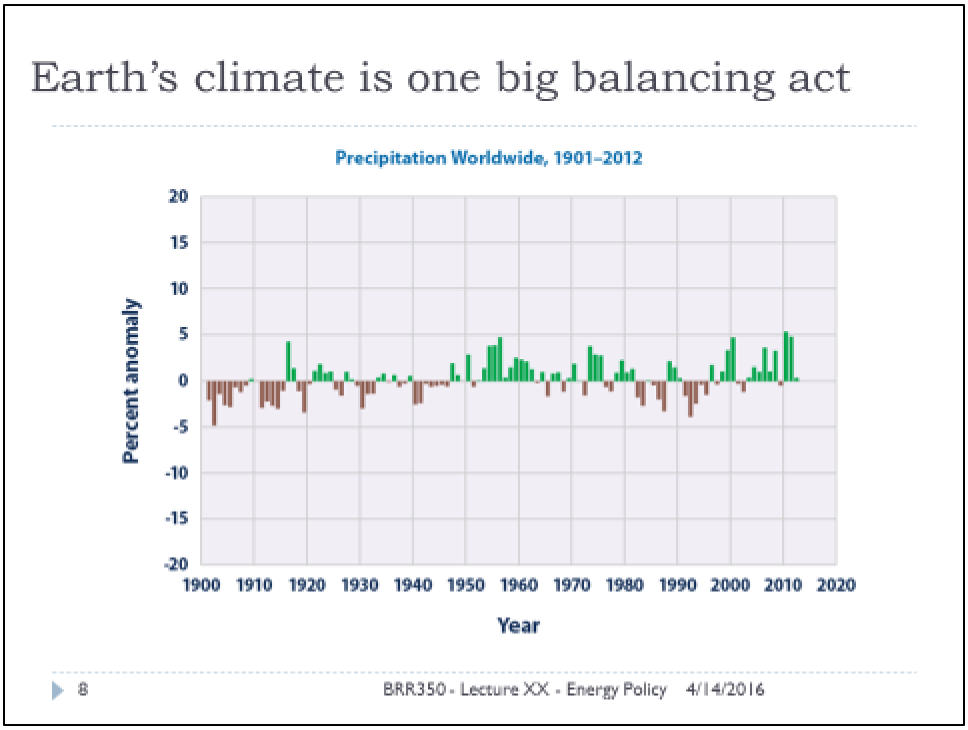
An equally challenging area to consider is the great plains and the Ogallala aquifer that has provided the vast majority of the water needed for corn production in that area. This massive aquifer is one of the largest sources of groundwater in the world and unfortunately we are fairly quickly using it up. According to a 2013 report by a research hydrologist at the United States Geological Survey (USGS), the depletion between 2001–2011, used up about 32 percent of the cumulative depletion during the entire 20th century. That's like saying in the last 10 years we have used up a third of all the water we have used up in the last 100 years … at that rate me, you and everyone we know will all get to see what happens when it pretty much runs out in the next 20-30 years.

In the United States, the biggest users of water from aquifers include agricultural irrigation and oil and coal extraction/utilization. We use massive quantities of water to grow plants and we use massive quantities to generate energy and we use massive quantities to refine petroleum and make chemicals. No one is sure what will happen when the water runs out because it hasn't happened yet, but you can be confident that technologies and processes and aspects of society unable to become more sustainable and recycle more will be facing dramatic changes.



http://www.epa.gov/climatechange/science/indicators/weather-climate/precipitation.html

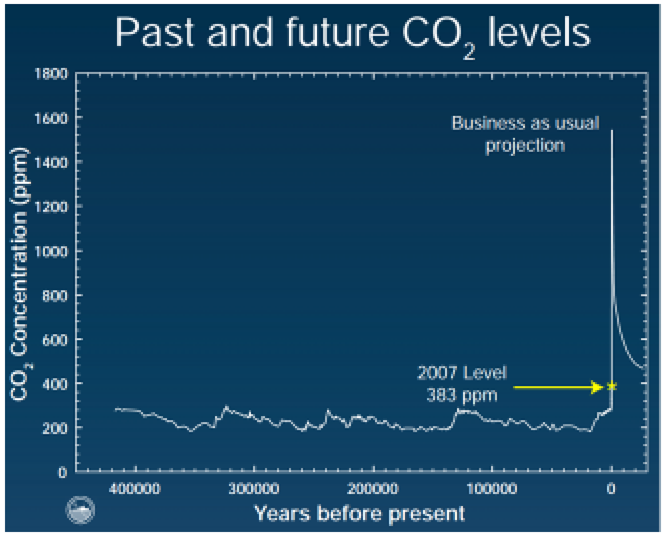
The climate works on a earth scale, not a human lifetime scale. So, one of the best ways to consider it is based on decades or centuries, not year to year. Even though mega droughts have a high probability of happening in some areas of the U.S., from a century perspective other areas are getting more and more rain. The U.S. spans an entire continent, so as a country we get an interesting cross section of experiences based on climate change. The thing to remember here is that weather is always changing, it’s the speed at which it changes that technically concerns us the most.



http://www.epa.gov/climatechange/science/indicators/weather-climate/precipitation.html

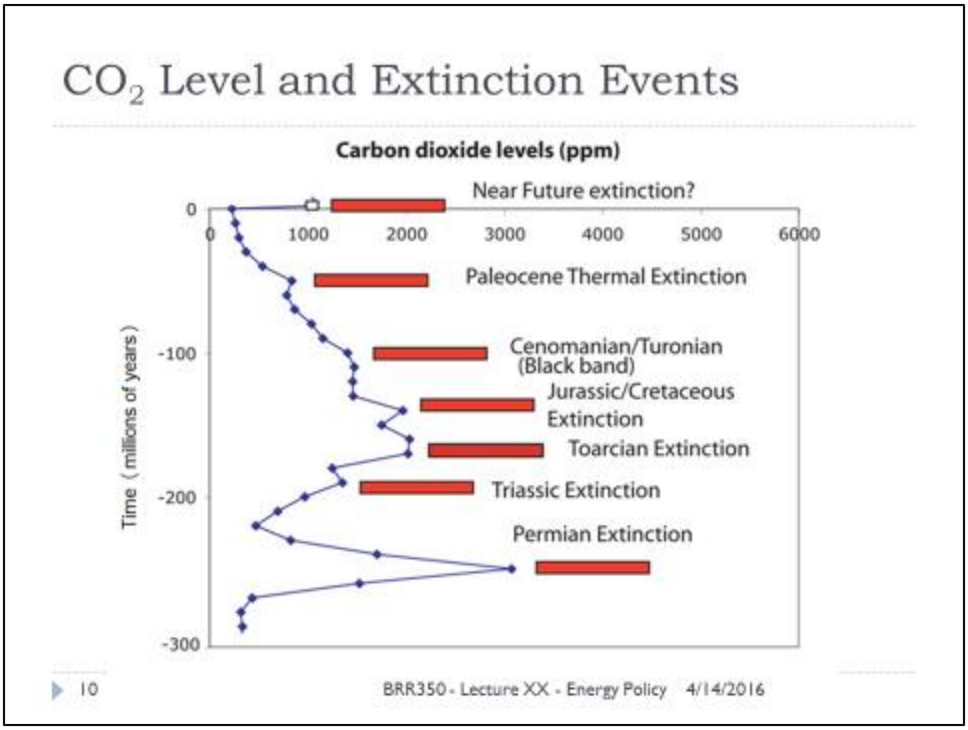
Given that Earth’s climate is one big balancing act graphs like this tend to support that things go in cycles. We have almost no idea how large the cycles are and exactly how they work because our technology has only recently become good enough to even consider things like this, but it makes sense that some kind of cycle is always occurring. Based on this graph it looks like on average earth is getting more rainfall than it has in awhile due largely to an increase in the number and strength of storms bringing precipitation. Information like this has to be weighed against data that extends back into time even further.

Impact of human activity on recent CO2 levels



http://co2now.org/current-co2/co2-now/
http://scrippsco2.ucsd.edu/presentations/ralph_keeling_presentations.html

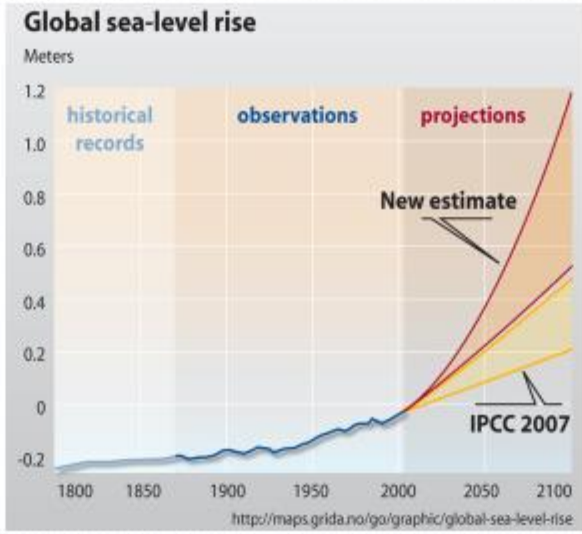
Carbon dioxide is indeed a GHG, but it has been in the atmosphere before life existed. So why are we concerned? The most significant concern is that the level of carbon dioxide, as well as other GHGs, are changing at very high rates, probably as a result of human activities. The level of CO2 has increased a lot in the last 2,000 years and if ice and sediment studies are correct, once it hits a certain threshold it tends to grow very rapidly until major earth scale ecological processes can correct it. Much like the moisture, there is considerable evidence that CO2 fluctuations happen in cycles, but humanity hasn't lived through one of these spikes yet and given our role in the tipping point, there is reason to be concerned about what the next few centuries will bring.



http://climatecrocks.com/2011/01/31/graph-of-the-day-co2-and-extinction-events/

Earth has been through some dramatic changes in CO2 level and temperature in the past, many seem to coincide with extinction events. Humanity has not been through one of these yet, so we are rightfully worried about what to expect. We have no idea if we can survive an Earth driven extinction period or how fast it happens, or even why. The last time the atmospheric temperature rapidly increased with a surging CO2 level was the end of the Permian era, about 252 million years ago. When that happened over 93% of the living species on Earth went extinct. This was possibly caused by heat, or by the increased acidity in the oceans, or by some other factors, we aren't 100% sure. However, if CO2 and rising temperatures can be relied on as indicators or extinction events we may live to see what happens during one.

Its already happening, but it can always happen faster



CO2 is going up, temperature is going up, ice caps are melting, and sea levels are rising. It's not a projection anymore, it's a proven fact that this is happening. The only thing we aren't quite sure about is how fast it will end up going and when it will stop. Given that the vast majority of Earth's population lives in coastal areas, this will absolutely effect our way of life. The earth is nothing more than a complex, well engineered spaceship, so hopefully these changes force us to figure out better ways to live on it.

http://www.theatlantic.com/health/archive/2009/09/on-urban-farms-a-sense-of-place/26675/
http://newswatch.nationalgeographic.com/2012/02/10/even-your-evian-was-pee-at-some-point/
http://af.reuters.com/article/commoditiesNews/idAFLDE6A01DQ20101114?pageNumber=3&virtualBrandChannel=0&sp=true
http://www.permaculture.co.uk/news/2306145216/germany-breaks-solar-power-records-again

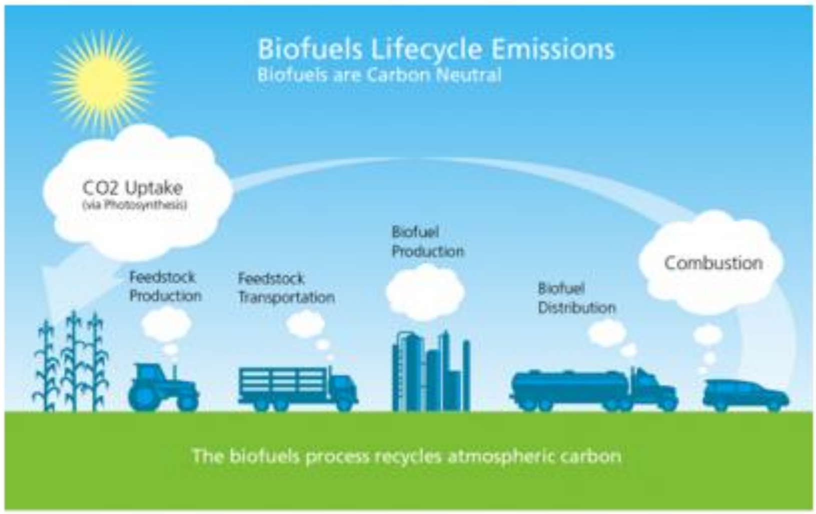
The city of Las Vegas has one of the most advanced water systems in the world. ~94 percent of the water that hits a drain anywhere in the Las Vegas metro area is recycled, cleaned to just-below drinking water standards, and returned to Lake Mead, the reservoir from which Las Vegas draws virtually all its drinking water. 94% was world class when this statistic came out an apparently it is even higher these days. At the country scale, Israel is the leading example. As of 2010, Israel leads the world in the proportion of water it recycles. As a country Israel recycles 80% of its wastewater, and 100% of the wastewater from the Tel Aviv metropolitan area is treated and reused as irrigation water for agriculture and public works.

The cost of reclaimed water exceeds that of potable water in many regions of the world, where a fresh water supply is plentiful. As fresh water supplies become limited from distribution costs, increased population demands, or climate change reducing sources, it is expected that demand for this kind of water will continue to rise.

Another interesting development is solar energy in Germany, a country without much gas, uranium deposits, and ironically sunny days. Germany is well known for cloudy days and long winters and yet in 2014 a record 50% of its power generation was solar and 90% of this solar power is from rooftop panels. They do not have a perfect system, but that level of solar power makes them far less reliant on power coming from other countries that is subject to geopolitical and weather related issues.

The overall point here is that sustainable technologies are a lot more than just a way to reduce greenhouse gases, in many cases they are just a smarter way of doing business as more and more people continue to fight over fewer and fewer resources that due to climate change are getting harder and harder to access and predict. Sustainability and sustainable technologies are about doing more with less and using what is available in close proximity, they will absolutely play and increasing role in our lives in the coming decades, so it's a topic worth thinking about.

Are biofuels carbon neutral? Is it even possible to have a carbon neutral fuel?



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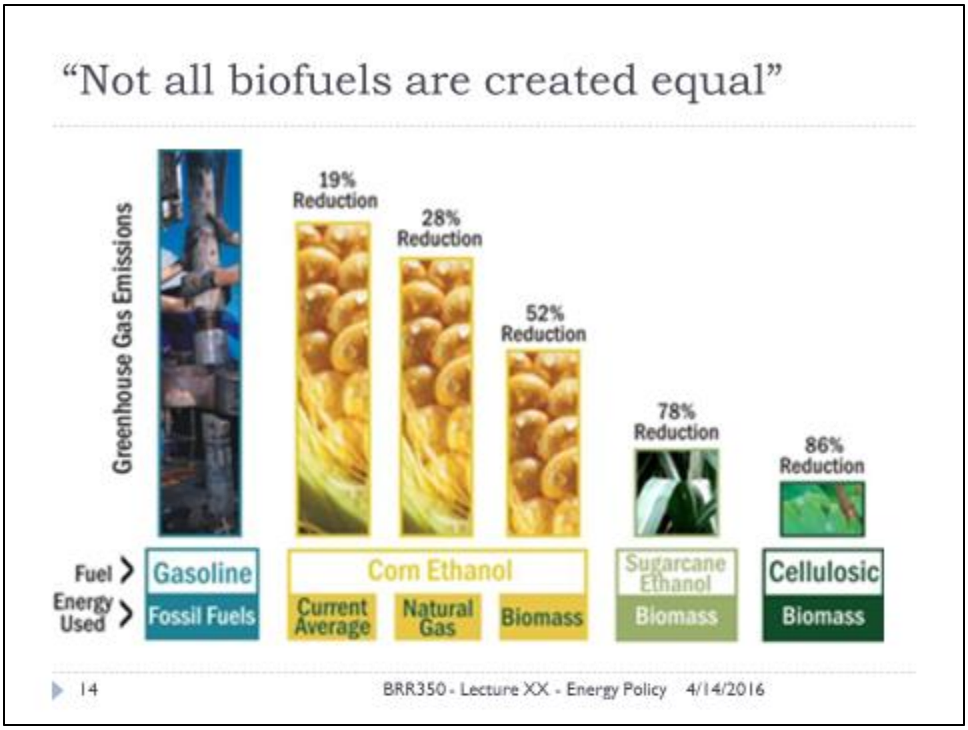
When we think about sustainability and biofuels we need to think about more than just the strict definitions for greenhouse gases and carbon neutrality. There is a bigger ecological scope that must be considered.

When we think about the true level of sustainability of a bioenergy process we must consider emissions, water usage, land acreage required for the biomass production, transportation, biofuels production and distribution. We tend to focus on emissions and not water usage or land acreage, but they are equally if not more important and because biofuels are still a fuel, they will eventually be burned and utilized at a scale congruent with the size of the market.

If we say that they fuel production processes for fossil fuels and biofuels are equally bad, then that really leaves us focused on biomass production, transportation and distribution. Given that it's a fuel, we might also be able to say that distribution will pretty much be the same. This leaves us with biomass production and biomass transportation which we know to be fairly acreage intensive compared to drilling a hole in the ground and pumping the product through pipelines, but probably similar in terms of water usage since fossil fuels production uses a lot more water than people realize. However, growing biomass certainly removes CO_2 from the air through biomass production and that is an extremely desirable goal to counteract all the CO_2 we emit when we burn fuels.

There is a lot to be said for understanding how to leverage living things and biomass chemistry to avoid spending more water, emissions and land utilization than we have to, but it is a much more complicated situation than just casting biofuels and other renewables as more sustainable because they utilize an energy source perceived to be naturally recharging.

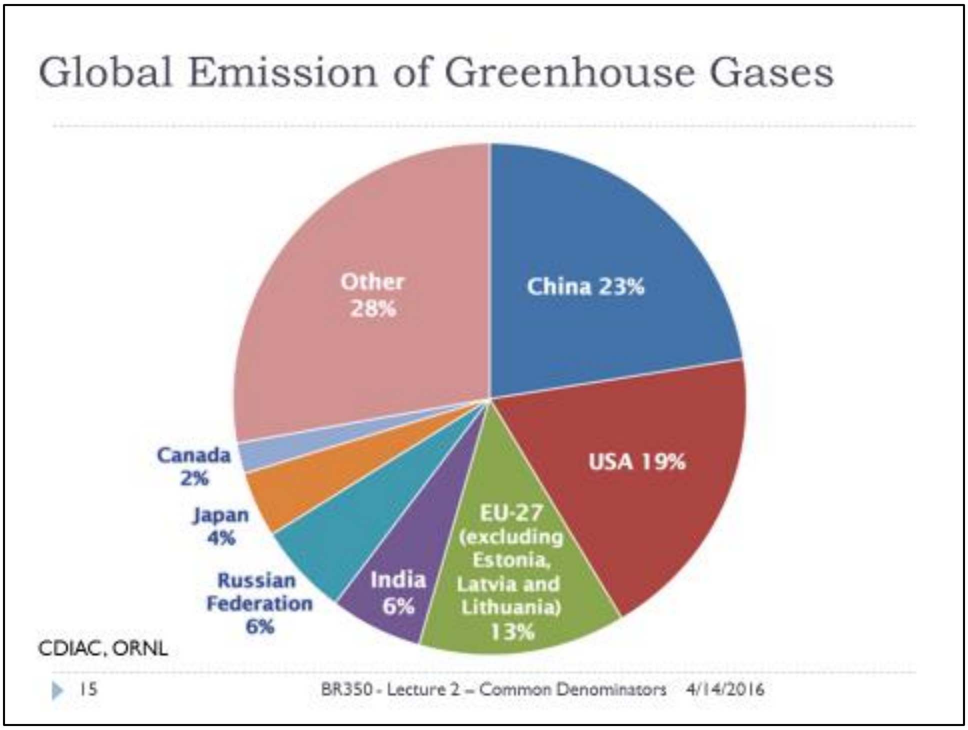


Wang et al. Environ. Res. Lett. 2 (2007) 024001

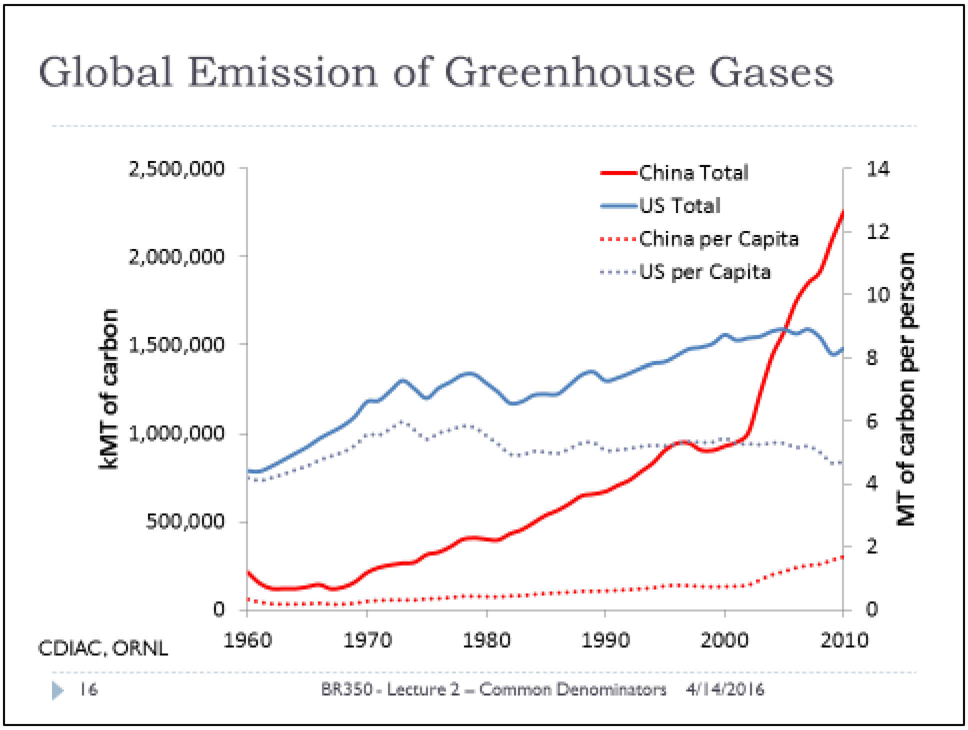
Using biofuels as alternative transportation fuels could reduce GHG emission, but the extent of reduction varies depending on how the biofuel was produced. Growth of corn involves many farming practices that introduces emissions, such as the application of fertilizers, herbicides and pesticides. Producing ethanol from corn grain also consumes heat and power, which have GHG emissions on their price tags. Some corn ethanol plants are powered by coal, which further compromises the GHG reduction effect of the biofuel.

Cellulosic ethanol could be a more appealing alternative to corn ethanol from a GHG perspective. The combustion of lignin provides heat and power, and the farming intensity and soil erosion for energy crops is often lower than what is necessary for growing corn.

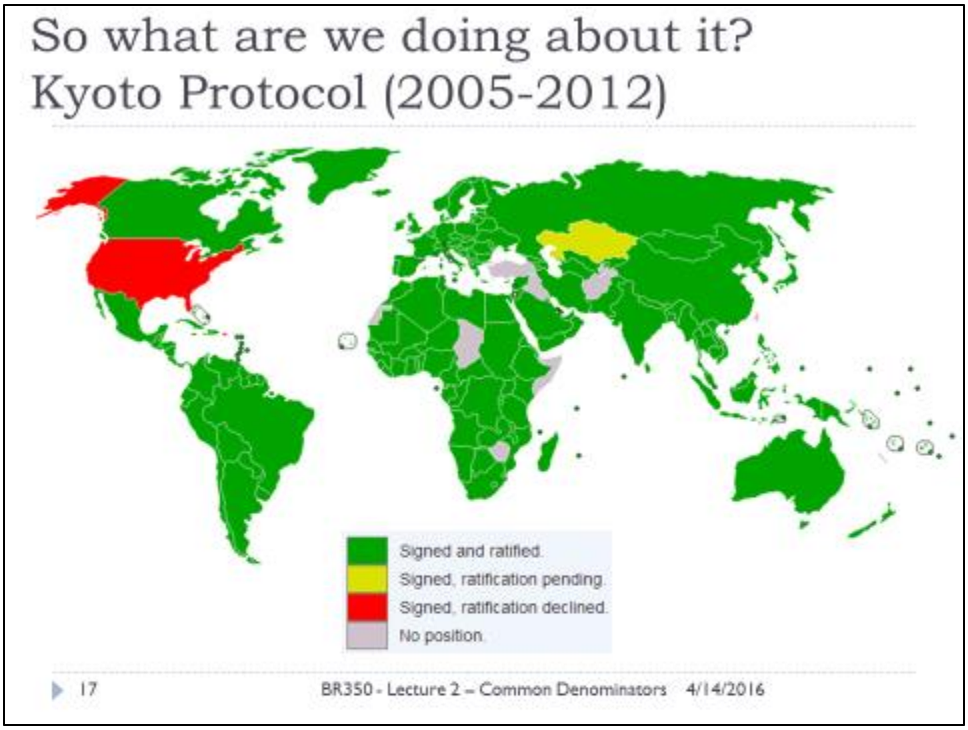
However, new studies are coming out that suggest even more complications since many of the current cellulosic ethanol plants plan to use some of the corn stover that would have previously been left of the fields. Corn stover left of the fields eventually decomposes generating CO2 and CH4 anyways, but a decent portion of it remains as solid carbon that improves soil quality and helps prevent erosion. By converting this to fuels we are sacrificing this solid carbon portion and potentially making the soil less sustainable from a water and fertilizer perspective. There is no question that many biofuels are more sustainable than fossil fuels, but certainly not all of them depending on the source of biomass and how the biofuel is produced.



From a country perspective, the U.S. has been responsible for having the most GHG emissions until very recently, when China took the lead. Burning coal, driving cars, and manufacturing seem to go hand in hand with high production of GHG's. If you remember the map of Earth at night, you can roughly say that the areas with the most lights are comfortably responsible for over 50% of the GHG emissions on Earth. That is not a particularly fair situation given how few areas are lit, but it certainly suggests relationships between emissions and lifestyle.



Even though the media frequently discusses the levels of GHG being emitted from China. China really only surpassed the U.S. about a decade ago. It is particularly important to note the differences in per capita CO2 emissions. The per capita emission in China is still much less than the per capita emission in U.S. because most of the emissions are associated with manufacturing to support massive export industries and not extravagant lifestyles. The U.S. on the other hand has outrageous per capita emissions because of our lifestyles rich in energy utilization and vehicle driving. Both countries have work to do to improve their emissions profiles. However, if the GHG emission in China keep increasing at the current rate, the total GHG emission in China will be twice as much as that of U.S. by 2020, which is a fairly dramatic increase.



http://en.wikipedia.org/wiki/Kyoto_Protocol

To address the global problem of GHG emission, the Kyoto Protocol was introduced in 1997 and was in effect from 2005 to 2012. The purpose of the Kyoto Protocol was to limit and reduce GHG emissions. Only the most industrialized countries were bound to meet specific emission reduction targets, but developing countries with low incomes were not bound to emission reduction because it could impede their economic development.

The Kyoto Protocol is a controversial topic that caused heated policy debates in the U.S. and other industrialized nations. After its expiration in 2012, the Doha Amendment was introduced as an extension, but it has only just come into effect. An important component of the Kyoto Protocol was the flexible mechanisms for emissions reduction. These mechanisms represent some valuable approaches for constructive reduction of GHG emissions using economic incentives. One of these was carbon taxes and similar emissions trading approaches that we previously discussed. Others are joint implementation and clean development mechanism.

http://cdm.unfccc.int/about/dev_ben/ABC_2012.pdf

The Kyoto Protocol outlined common, but differentiated responsibility in emission reduction among industrialized countries, also know as the Annex I nations, and the developing countries, aka the non-Annex I nations. The clean development mechanism is introduced under this arrangement to motivate developed countries to provide funds and technology to developing countries, as an ALTERNATIVE way for meeting their OWN GHG reduction targets.

Emission reduction projects conducted in developing countries are awarded certified emission reduction credits or CERs, and each credit is equivalent to one ton of CO2. Certified emission reduction credits can be traded among countries to meet emission targets, so the mechanism provides an economic incentive for emission reduction. Projects that generates CERs include biofuel production, biofuel consumption, nitrous oxide abatement,or energy efficiency improvement projects.

The image is from a unique wind farm in China that is also the largest windfarm in Asia. Netherland is the major beneficiary of the project, which reduces 50,000 tons of CO2 emissions per year. Another example comes from a biomass processing plant in Kenya called Karan Biofuel. A company from UK participated in the development of the project and Karan Biofuel is actively involved in CER trading.

http://ji.unfccc.int/about/multimedia/ji_highlights.pdf

Joint implementation is another flexible mechanism included in the Kyoto Protocol, which allowed committed countries to build emission reduction and emission removal projects in other committed countries, for the purpose of meeting emission targets. It is similar to Clean Development Mechanism, and it has a transferrable credit called an emission reduction unit or ERU which is roughly equivalent to the CER we just discussed.

In the picture on the left a truck is dumping sawdust into a biomass power plant in Romania. Before the plant was built in the area with help from Denmark, sawdust was dumped in the forest as a waste. This power plant is expected to generate 500,000 ERUs between 2008 and 2012.

The picture on the right is a biodiesel production facility in Bulgaria. A company from Austria participated in the development of the project. The plant has the capacity of producing 60,000 tons of biodiesel per year from sunflower and canola crops and is worth tens of thousands of ERU’s.

So what do you think? How can we use bioenergy to be more sustainable?

We know Earth isn't flat anymore, but as early as 600 years ago that was a conventional belief. As a closing thought, I would like you to think about how we can use bioenergy to be more sustainable. It would be impossible for any of us as individuals to single-handedly stop climate change, but developments like bioenergy still have the potential to be far more sustainable than fossil fuels and that will have value regardless of the current climate conditions. Please take a moment to think about how we could use biomass smarter and more efficiently to meet our needs while improving conditions on Earth so that future generations will have a functioning planet.