What is Carbon Dioxide?

- A colorless, odorless gas produced by burning carbon and organic compounds and by plant respiration.
- Non-toxic gas that in its solid form is known as “dry-ice”.

Deposition occurs at -78.5 °C (-109.3 °F)
Carbon in our atmosphere

- 0.04% by volume (400 ppm)
- The Keeling Curve is a graph which plots ongoing CO₂ concentration in the Earth's Atmosphere since 1958.
- Based on continuous measurements taken at Mauna Loa Observatory (MLO) in Hawai‘i under the supervision of Charles David Keeling
- Seasonal cycles
- Steady year to year increase
Highest CO$_2$ Last ~800K yrs

CO$_2$ & Air Temperature are well correlated
Senate Votes (January 20, 2016)

• Sheldon Whitehouse (D-R.I.) “Climate Change is Real”.
  – PASSED (98-1)

• Brian Schatz (D-Hawaii) that stated, “climate change is real and human activity significantly contributes to climate change.”
  – FAILED (50-49)
How has science concluded that humans are responsible for the increase of CO$_2$ in the Earth's Atmosphere?

“I think you should be more explicit here in step two.”
• Elements are presented in order of increasing atomic number.
Science has proven that fossil fuel emissions are changing atmospheric composition through the use of stable isotopes.

• What the heck is an Isotope?
• Isotope – different types of atoms of the same chemical element all having a different number of neutrons therefore a different atomic mass.
• There are 3 naturally occurring carbon Isotopes. $^{12}C, ^{13}C, ^{14}C$
Calculating Atomic Mass

• Protons + Neutrons = Atomic Mass

• If Carbon (C) has 6 protons then:
  – 6 protons + 6 neutrons = 12 = $^{12}$C (Stable) - 99%
  – 6 protons + 7 neutrons = 13 = $^{13}$C (stable) - 1%
  – 6 protons + 8 neutrons = 14 = $^{14}$C (unstable) - 0.00001%

As you can see all three isotopes have a different atomic mass and Carbon-12 ($^{12}$C) is the most abundant.
What does Isotope stability mean?

- $^{14}\text{C}$ is an unstable isotope which means it decays over time.
- It has a half life of 5730 years

Using the $^{14}\text{C}$ isotope is possible to go back ~50,000 yrs
Stable Carbon Isotopes.

- $^{12}\text{C}$ and $^{13}\text{C}$ are stable isotopes which means they do not decay over time.
- $^{12}\text{C}$ and $^{13}\text{C}$ can be used to tell us about our current atmospheric chemistry and allow us to compare it the chemistry of the past.
- The atmospheric concentration ratio between these two isotopes also provides us the evidence we need to determine the amount of anthropogenic inputs of $\text{CO}_2$ into the atmosphere.
To understand this you need to first know something about photosynthesis.

• Plants draw in CO\textsubscript{2} from atmosphere and use the energy from the Sun to fix the inorganic carbon into a useable organic form.

• Plants prefer to take in \textsuperscript{12}CO\textsubscript{2} because the lower atomic mass (12) of this isotope requires less energy to process than \textsuperscript{13}CO\textsubscript{2} (atomic mass 13).

• Therefore plants discriminate against \textsuperscript{13}CO\textsubscript{2}. In other words, it’s not there favorite “flavor”
• If plants prefer $^{12}\text{CO}_2$ over $^{13}\text{CO}_2$ then there should be a steady ratio of $^{13}\text{C}/^{12}\text{C}$ in the atmosphere (assuming biomass doesn’t change much).

• How is it possible then to determine the atmospheric anthropogenic inputs of CO$_2$ using isotopes?

• First we have to ask some questions.

  – What is the main source of anthropogenic CO$_2$ to the atmosphere? **Fossil Fuels**
  – What are fossil fuels made of? **Plants**
  – What type of carbon atom is associated with plants? **$^{12}\text{C}$**
  – If fossil fuels are burned what will happen to the $^{13}\text{C}/^{12}\text{C}$ concentrations in the atmosphere? **Decrease**
Part 2

the carbon footprint

- water
- emissions
- fuel
- electricity
- personnel
- transport
- gas
- offsets
- recycling
- waste
What is a carbon footprint?

• **Carbon Footprint** – a measure of the impact that human activities have on the environment in terms of the amount of greenhouse gases (GHG) produced, measured in units of CO$_2$.
  – Measures the total greenhouse gas emissions caused directly and indirectly by a person, organization, event or product.
  – Is calculated by considering the amount of greenhouse gas emitted/removed or embodied in the life cycle of a product.
Why is CO$_2$ used to measure footprints?

- **Radiative Forcing** – is a measure of the net change in the energy balance of the Earth system in response to some external perturbation.
- Measured in W m$^{-2}$. **Positive** = warming and **Negative** = cooling
- 61% of the forcing is a result of CO$_2$.
- 17% of the forcing is a result off CH$_4$.

IPCC (2013)
Life Cycle Methodologies

• Many companies do not account for the entire supply chain that results in final goods and services.
  – Overlook up to 75% of the GHGs involved.
  – Are there better ways to calculate a carbon footprint?

1. Cradle to Grave – Full life cycle of a product. – resource extraction to disposal phase.
2. Cradle to Gate – partial product life resource extraction to factory gate. (Use and disposal are omitted.)
3. Cradle to Cradle – product is recycled.
4. Gate to Gate – looks at only one value added process
Green house gases have different atmospheric concentration and different strength as a GHG.

Because of this variability, carbon footprints are measured in tons of CO$_2$ – eq, or the tons of CO$_2$ that would cause the same level of radiative forcing as the emissions of a given GHG.

Total GHG Emissions 2013 in the U.S.

GHG emission from transportation have increased by a 18% since 1990.

- Over 90% of the fuel is petroleum based.
- Due to increased demand for travel
- Stagnation of fuel efficiency.

Over 70% of our electricity comes from burning fossil fuels, mostly coal and natural gas.

http://www.epa.gov/
An atlas of pollution: the world in carbon dioxide emissions

Carbon Dioxide emissions by country

<table>
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<th>Table id</th>
<th>Rank</th>
<th>Country or region</th>
<th>2008, mil tonnes</th>
<th>2009, TOTAL, mil tonnes</th>
<th>2009, per capita tonnes</th>
<th>% change, 2008 to 2009</th>
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<td>1,228.65</td>
<td>1,219.78</td>
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</table>
• Can you see any differences between GHG EMISSIONS and PER CAPITA Emissions?
Per Capita CO$_2$ Emissions

- Global Avg. = 4 tons of CO$_2$ -eq/yr
- USA Avg. = 20 tons of CO$_2$ -eq/yr
• Primary footprint is dominated by transportation and household electricity use.

• Secondary footprint is dominated by diet, clothing and personal products.

A study by the Renewable & Appropriate Energy Laboratory at UC Berkeley shows who you are and where you live makes a big difference in the activities that have the largest impact on your carbon footprint.

• California = Low electricity (5%)

• St. Louis = High electricity (25%)

http://coolclimate.berkeley.edu/
Where do you think the carbon footprint bigger, cites or suburbs?

Studies have shown that urbanization can deliver large carbon reductions by reducing per capita energy use in transport housing and construction.

New study shows that this is offset by suburban areas.

Carbon footprint actually increases until you reach 3000 person per square mile.

Jones and Kammen (2014)
Carbon Visuals

• If we could see carbon dioxide would we take it more seriously?

Carbon Credits

- **Carbon Credit** = 1 tonne of CO$_2$–eq either removed, avoided or sequestered.
  - Renewable energy
  - Forestation and afforestation
  - Energy efficiency
  - Methane capture

- The Carbon credit system was ratified in conjunction with the Kyoto Protocol.

- Credits are traded on the international market.

- Two Markets
  - Voluntary carbon offset market
  - Compliance carbon offset market (Cap and Trade)
Who Gets the Money?

- In the **voluntary market** – carbon offsets are used to fund projects which absorb or eliminate an amount of carbon dioxide gas that is equal to the amount emitted.
- In the **compliance market** companies profit by reducing their footprints and selling their right to produce CO\textsubscript{2}. (Cap and Trade)
- China is rolling out the worlds largest cap and trade system this year.
Does it actually Work?

• Essentially, carbon offsets work by allowing polluters to pay others to make their carbon reductions for them.
  – Reduce personal responsibility? (do what I want without guilt?)
  – License for large companies to pollute freely
  – Corruption?
• Are offset services actually being provided
• Are companies reporting correctly
  – Is this superior to the idea of a carbon tax?

The American Clean Energy and Security Act (ACES) was approved by the House of Representatives on June 26, 2009 by a vote of 219-212, but was defeated in the Senate.
Carbon Tax

• **Carbon Tax** – polluters will pay per tonne of carbon they release into the atmosphere.
  – Price will be set at $40 and increase gradually
  – The amount of carbon pollution involved in producing a product would start to be factored into its final price.
  – Products produced through dirty processes will become more expensive.
  – Encourages to businesses to switch to clean energy sources.

• Finland was the first country in intact a carbon tax in 1990.


• Boulder (Colorado) – first in the US (2007) -7$ per ton of carbon

http://www.nature.com/news/us-republican-idea-for-tax-on-carbon-makes-climate-sense-1.21477
Part 3
Where are we now? Where are we headed?
Anthropogenic “Forced” Change
Concentrations of Greenhouse Gases from 0 to 2005

- Red line: Carbon Dioxide (CO₂)
- Blue line: Methane (CH₄)
- Black line: Nitrous Oxide (N₂O)

Year:
0 500 1000 1500 2000

CO₂ (ppm), N₂O (ppb):
250 300 350 400

CH₄ (ppb):
600 800 1000 1200 1400 1600 1800 2000
Our Current CO₂ Concentration

Jan. 2017: 406.07 ppm
Jan. 2016: 402.52 ppm
Jan. 2015: 399.96 ppm

On May 9th (2013) the daily average of carbon dioxide (CO₂) in the atmosphere passed the 400 ppm mark

Increasing at a rate of 2.89 ppm/yr

Preindustrial levels 280 ppm
During 2016, the average temperature across global land and ocean surfaces was 1.69°F (0.94°C) above the 20th century average. This was the highest among all 137 years in the 1880–2016
Deniers of Change

- Elected House Majority leader Paul Ryan. “I don’t know the answer to that question and I don’t think science does either.”

- Senator Jim Inhofe of Oklahoma is the new Chairman of the Environmental and Public works committee.

- He has written a book dismissing climate science as a hoax.

Senator James Inhofe
#1 Threat to Planet Earth
The Anti-Science Climate Denier Caucus

Over 56 percent of Republicans in the 114th congress either denied or questioned the science behind climate change.

170 elected representatives have taken over $63.8 million from the fossil fuel industry that’s driving the carbon emissions which cause climate change.

http://thinkprogress.org/climate/2015/01/08/3608427/climate-denier-caucus-114th-congress/
Contributions from the fossil fuel industry

• 38 Climate Deniers in the Senate have taken
  – ~28 million dollars

• 131 Climate Deniers in the House have taken
  – ~35 million dollars
Our Elected Officials

- **Senator Lisa Murkowksi**, (R-AK) – Incoming Chairman, Energy & Natural Resources Committee, $733,144 from oil and gas industry in her career
- **Sen. Mike Enzi** (R-WY), $489,933 from oil and gas industry in his career
- **Ex-Governor Rick Perry** (R-TX), $977,624 from oil and gas for his 2012 Presidential Campaign
- **Speaker John Boehner** (R-OH), $1,463,788 from oil and gas industry in his career
- **Previous Senate Majority Leader Mitch McConnell** (R-KY), $1,783,169 from oil and gas industry in his career.
- **Senator Mitch McConnell** (R-KY), $1,783,169 from oil and gas industry in his career
- **Senator Rand Paul** (R-KY), $129,305 from oil and gas industry in his career
- **Senate Majority leader Rep. Paul Ryan** (R-WI), on whether human activity causes climate change, $508,549 from oil and gas industry in his career.
- **Senator Ted Cruz** (R-TX), $932,568 from oil and gas industry in his career
- **Ex-Rep. Steve Stockman** (R-TX), $118,100 from oil and gas industry in his career
Future Scenarios

• We are currently on the greatest trajectory (RCP 8.5).

IPCC (2013)
There is still hope

Conference of the Parties (COP)

- The Conference of the parties is the supreme body of the United Nations Framework Convention on Climate change (UNFCCC).
Timeline of significant COP meeting outcomes

COP 1
Berlin, Germany

COP 3
Kyoto Japan
Annex 1 countries reduce emissions by 6-8% (USA 7%) below 1990 levels.
Clinton sings but Congress does not ratify.

COP 6 – Bonn Germany,
George Bush Rejects Kyoto protocol and USA does not participate in negotiations.

COP 15
Copenhagen, Denmark
Major issues are avoided and pushed into the future.

COP 18
Doha, Qatar
Amendment of the Kyoto Protocol 2nd commitment

COP 19
Lima, Peru
Call for climate action (192 countries)
Laid groundwork for a binding agreement.

COP 20
Lima, Peru
Call for climate action (192 countries)
Laid groundwork for a binding agreement.

COP 21
Paris, France
A new international agreement on climate applicable to all countries with the aim of keeping global warming below 2°C.

COP 22
Marrakech, Morocco
Clear Paris agreement
Full decarbonization 2040

131/197 Parties have ratified

- Keep global temperatures below 2°C (optimistically 1.5 °C)
- Limit the amount of GHG’s to what the Earth can absorb naturally.
- To review each countries contribution to cutting emissions every 5 years.
- Rich countries help poorer countries.
- On 4 November 2016 the Agreement went into force.
HOW?

• Crops for carbon capture?
  – 1/3 of total arable land on the planet. 1/3 land in the U.S.
  – Loss of terrestrial species perhaps worse than climate change itself.

• Plowing biochar into agricultural plots?
  – Earths albedo would be decreased
  – Add pulverized reflective rock like silicate to offset this
  – To cut 12% of emissions would take 45% of the Earths land surface.
  – Huge environmental implications as a result of the mining not to mention huge costs ($60 Trillion).

• Ocean fertilization with Iron to increase its ability to store carbon?
  – Unintended consequences to Marine Life
The Target Must Be Zero

• Longer term sea level rise impacts will continue well past the 21st century.
• As much as 1/3 of emissions could be cut by stopping deforestation.
• Renewable power
Thank You

Any Questions