



ATMOS 1020 Climate Change

6. Carbon Dioxide Emissions

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Today: Who's Responsible?

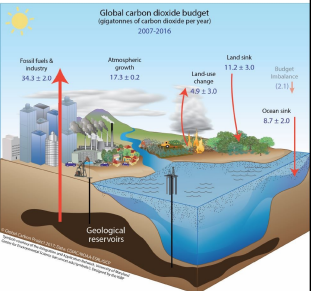
- How much are average emissions for:
 - Nations of the world
 - Citizen of the world
 - Average American
- Which economical sectors do emissions come from?
 - Transportation
 - Electricity generation
 - Industry

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What Happens to CO₂ Emissions?

- Not all CO₂ emissions go into the atmosphere
- A little **less than 50%** does actually...
 - 25% goes into the **ocean**; unfortunately this leads to ocean acidification (a future topic)
 - 30% goes into **land ecosystems**



Global carbon dioxide budget (gigatonnes of carbon dioxide per year) 2007-2016

Category	Value (GtC/yr)
Fossil fuels & industry	34.3 ± 2.0
Atmospheric growth	17.3 ± 0.2
Land use change	4.9 ± 3.0
Land sink	11.2 ± 3.0
Budget imbalance	12.1
Ocean sink	8.7 ± 2.0

CO₂ budget (2007-2016), showing the various net sources and sinks. Numbers are in Gt of CO₂ and not of C. The conversion factor is 44/12 (molecular weight of CO₂ divided by atomic weight of C). Source: Global Carbon Project.

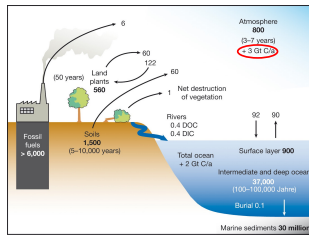
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The Carbon Cycle

All numbers in Gt C per year:

- Humans: $6 + 1 = 7$
- Land: $60 + 60 - 122 = -2$
- Ocean: $90 - 92 = -2$
- Natural Earth is a sink (-4) for CO_2 and removes about half of human emissions (7)
- Remaining 3 accumulates in the atmosphere
 - human component in atmosphere: 50% (420 ppm / 280 ppm)



Stocks are in bold (Gt C), fluxes are normal (Gt C per year)

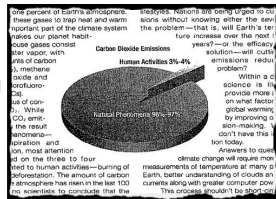
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How Exxon Argues

- “While most of the CO₂ emitted by far is the result of natural phenomena ..., most attention has centered on the 3-4% related to human activities – burning of fossil fuels, deforestation.”
- This is misleading!

 - focus on emissions (7 from humans, 120 by land) to give the false impression that human impact is small
 - completely ignores that land takes up more CO₂ (122) than it emits (120), but that humans do not take up CO₂

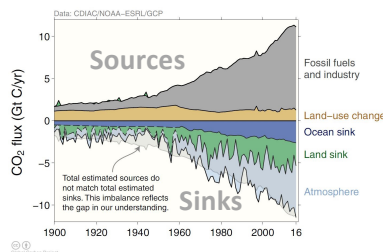


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Emissions Over Time

- Annual emissions
- Negative numbers mean net uptake
- Absorption by land varies greatly due to things like droughts, exceptional rains, or ENSO



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How Much CO₂ Is There?

- CO₂ is the main greenhouse gas
- Amount of CO₂ in the atmosphere: 3,000 gigatons (GT)
- World emissions (2020): 35 GT per year (ca. 1%)
 - 1 GT = 1 billion metric tons
 - 1 metric ton is a little more than a regular ton (2,000 pounds)
- It's important to know the numbers, but let's first talk about ways to visualize them

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The “Carbon Blanket”

- What if all the CO₂ in the atmosphere sank to the surface of the Earth and was in one layer of gas?
- Forming a CO₂ blanket all over the globe
- It would be **3.2 meters (10.5 feet) thick**
 - preindustrial (1750) thickness was **2.3 m** (7.5 feet)
- Adding to the carbon blanket
 - each year we emit the equivalent of **3.7 cm** (1.46 inches) to the blanket (+1%)
 - more than a **foot per decade**...

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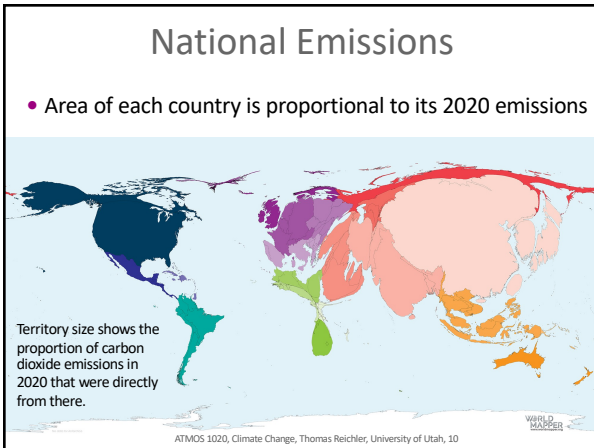
CO₂ vs. Other Pollutants

- Most pollution is felt near the source
 - air quality near urban centers or coal power plants
 - water quality near mining, etc.
- CO₂ is different
 - since CO₂ stays in the atmosphere for so long, everyone's emissions affect everyone else
 - this is truly a **global problem**
- Therefore, it makes sense to think about **who's responsible**



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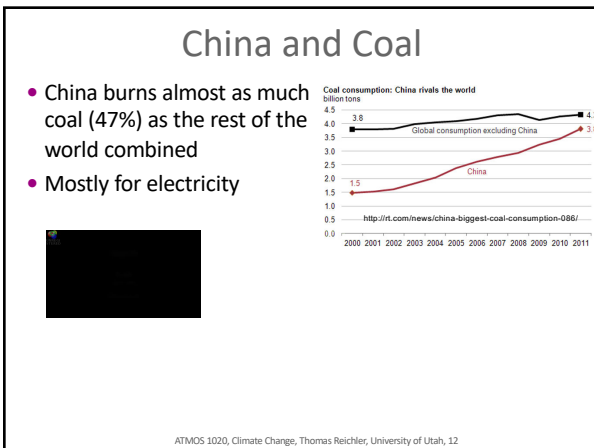
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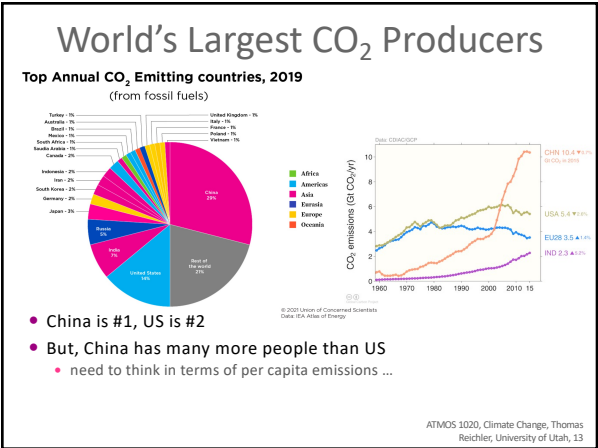
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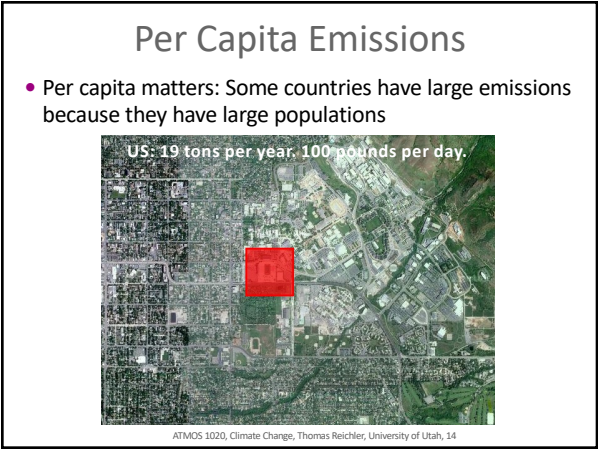
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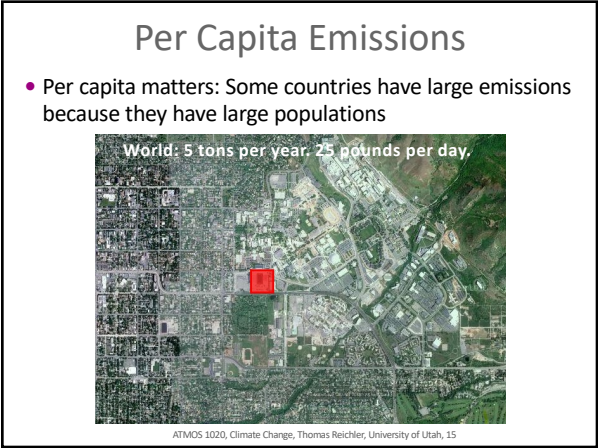
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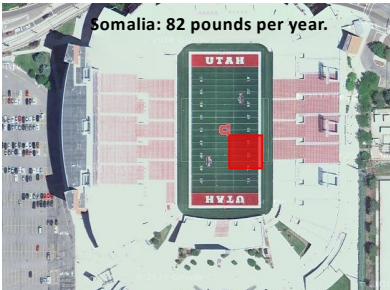
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Per Capita Emissions

- Per capita matters: Some countries have large emissions because they have large populations



Somalia: 82 pounds per year.

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Consumption-Based Emissions

- Emissions are typically measured in terms of 'production'
- But industrialized nations let other nations do much of their pollution
- How do emissions compare when we adjust for trade?
- Now Mongolia and Middle East is #1

Consumption-based carbon dioxide (CO₂) emissions are national or regional emissions which have been adjusted for trade (i.e. vertical producer emissions minus emissions embedded in exports, plus emissions embedded in imports).

No data 0.1 1.1 2.5 5.1 7.5 10.1 15.1 20.1 >20.1

<https://ourworldindata.org/consumption-based-co2>

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Historically Responsibilities

- CO₂ has long residence time
 - industrialized countries have been emitting for a long time
 - underdeveloped world is behind and wants to keep up
- Need to think in terms of cumulative emissions
 - US is #1 (27%)
 - followed by Russia (11%) and China (10%) (since the industrial revolution and in absolute numbers)

animated global CO₂ emissions

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Cumulative carbon emissions

*from fossil-fuels and cement production, in million metric tons of carbon (not CO₂)

Country/Region	Cumulative Emissions (million metric tons of carbon)	Percentage (%)
U.S.	96,955	27%
China	32,453	10%
Russia	31,431	11%
The rest of the world	93,877	28%
World	83,543	100%
Germany	5,100	6%
France	3,321	4%
India	685	1%
Japan	439	1%
Indonesia	338	1%
South Africa	1,000	1%
Mexico	1,000	1%
Brazil	1,000	1%

Data from Oak Ridge National Laboratory, ORNL. Cumulative since 1850: Argentina (1949), Brazil (1961), China (1970), Colombia (1970), Egypt (1970), France (1970), Germany (1970), India (1970), Indonesia (1970), Japan (1970), Korea (1970), Mexico (1970), Pakistan (1970), Peru (1970), South Africa (1970), U.S. (1970).

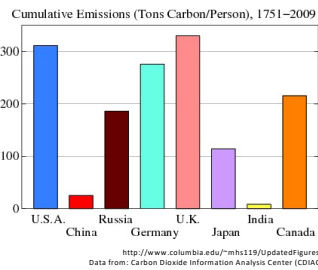
http://www.earthenergycollective.com/utahresponse/281360/who-is-most-responsible-climate-change-infographic

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Per Capita Cumulative Emissions

- Now, UK, US, and Germany are #1
- What if China reaches living standard of the western world?
- And other developing countries?



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Who's Responsible?

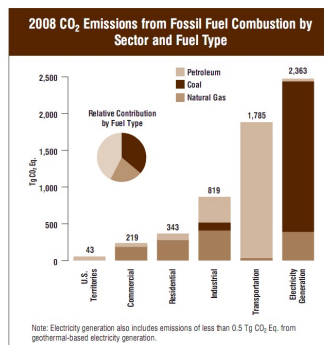
Many ways to cut up the emissions pie:

- Total emissions of a country
 - countries with large population tend to be high
- Per capita
 - industrialized countries tend to be high
- Cumulative
 - industrialized countries tend to be high
- Consumption-based
 - industrialized countries tend to be high

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US Emissions

- GHG emissions
 - CO₂ (95%)
 - CH₄ (4%)
- CO₂
 - electricity: 42%
 - transportation: 32%
 - 53% of this for personal vehicles
 - industry: 15%
 - residential + commercial 10%
- Largest emitters
 - power plants
 - oil refineries

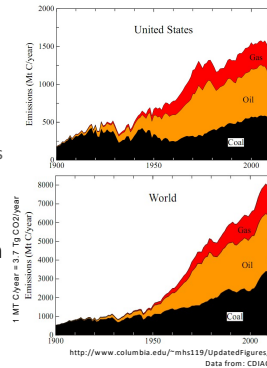


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What Makes Up the Emissions?

- Fossil fuel combustion accounts for 94% of CO₂ emission in the US (2008)
 - 1 gallon gas = 8.7 kg CO₂
 - let's say you drive 10 miles each way to the U and 20 miles per gallon: 18 pounds CO₂
- Coal: mostly for electricity
- Oil: mostly for transportation
- Natural gas: residential heating

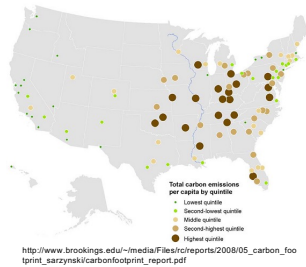


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Regional Breakdown

- Carbon footprint (in tons CO₂ per person per year)
 - Salt Lake: 9.3 (#50)
 - Los Angeles: 5.2 (#2)
 - Indianapolis: 12.4 tons (#99)
- Metro areas with largest footprints are in the East
- Factors?
 - population density, urbanization
 - public transportation, rail transit
 - climate
 - type of industry



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US Trends

- CO₂ emissions from fossil fuel burning increase by ~1% per year, 50% of this stay in the atmosphere
- Main reason
 - growing economy
- Industry is getting more efficient
- Residential is getting worse
 - partly due to larger homes
- Transportation is getting worse
 - more & larger cars, longer driving distances

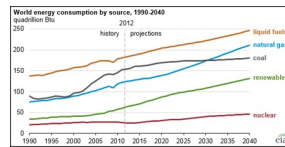


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Future Energy Consumption

- The world's energy consumption will increase by ~50% (2012-2040)
- 2015: fossil fuels supplied 83% of global energy demand
- 2040: fossil fuels will still meet more than 75% of world energy



Showstack, R. (2016). High energy growth, fossil fuel dependence forecast through 2040, *Eos*, 97, doi:10.1029/2016EO052301. Published on 13 May 2016

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Extra Slides

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Utah Emissions

- Utah: 40 MT CO₂/year
 - 0.7% of US
 - Utah population: 1% (3 Mio) of US
- 14 power plants
 - 33 MT/year
 - 75% of Utah's GHG emissions
- Salt Lake County:
 - U.S. Magnesium: ca. 1.5 MT (= 36% of county's emissions)
 - 2 refineries: 1 MT
 - Kennecott: 0.7 MT



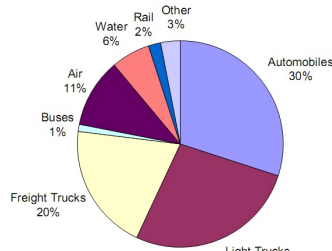
<http://www.ksl.com/index.php?sid=23976349&nid=148&title=power-plants-responsible-for-75-percent-of-greenhouse-gas-in-utah>

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US Transportation Emissions

- Transportation is responsible for **32%** of US carbon footprint (2005)
- Highway transport accounts for **80%** of this total
 - cars: 30%
 - light trucks: 27%
 - trucks: 20%



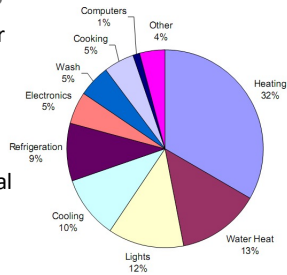
http://www.brookings.edu/~media/press/reports/2008/05_carbon_footprint_sarzynski/carbonfootprint_report.pdf

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US Buildings Emissions

- Buildings are responsible for **~40%** of U.S. emissions (2005)
 - residential and commercial each ~20%
- More than 50% of residential energy comes from **electricity**
 - most of electricity comes from coal power plants
 - power plants have only 35% efficiency
- depending on how electricity is used, as much as 97% of coal energy is lost



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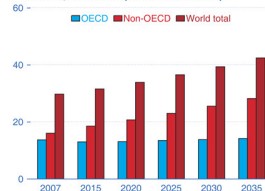
Future CO₂ Emissions

OECD (Organization for Economic Cooperation and Development)

= 30 industrialized countries:

- Developing world has already surpassed OECD countries in CO₂ emissions
- Developing nations will be a massive energy market in the future
 - what types of fuel will they use?
 - from where will it come?

Figure 10. World energy-related carbon dioxide emissions, 2007-2035 (billion metric tons)



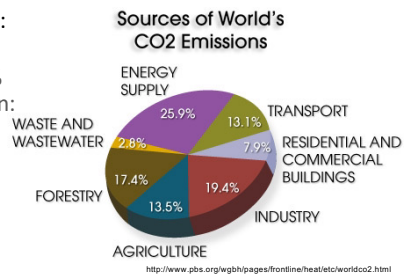
EIA U.S. Energy Information Administration
Independent Statistics and Analysis
International Energy Outlook 2010 (IEO 2010):
<http://www.eia.doe.gov/ia/ieo/index.html>

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World Emission Sources

- Primary sources:
 - energy: 26%
 - industry: 19%
 - transportation: 13%
 - buildings: 8%
 - forestry and agriculture: 31%



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