Confronting Climate Change

A Survey by Scott Sawyer

Via GreenPolicy360 / September 2019

Human activities are undermining the life support systems of the planet, and this is triggering catastrophic changes: Today, on land, sea, and in the air, the signs of resource depletion, ecosystem degradation, and anthropogenic climate change are widespread. Food system activities are major drivers of these changes and particularly vulnerable to these changes. The ability of food systems to prepare, mitigate, and adapt will be a major challenge for all societies.

800,000 years ago - present: During the past 800,000 years there have never been greenhouse gas (GHG) concentrations as high as current levels. Atmospheric carbon dioxide concentrations were at 408.6 parts per million in 2018, compared to a range of 200-300 parts per million during the past 800,000 years. Methane levels are at over 1,800 parts per billion compared to a range of 400-700 parts per billion during the past 800,000 years (Lüthi et al., 2008).

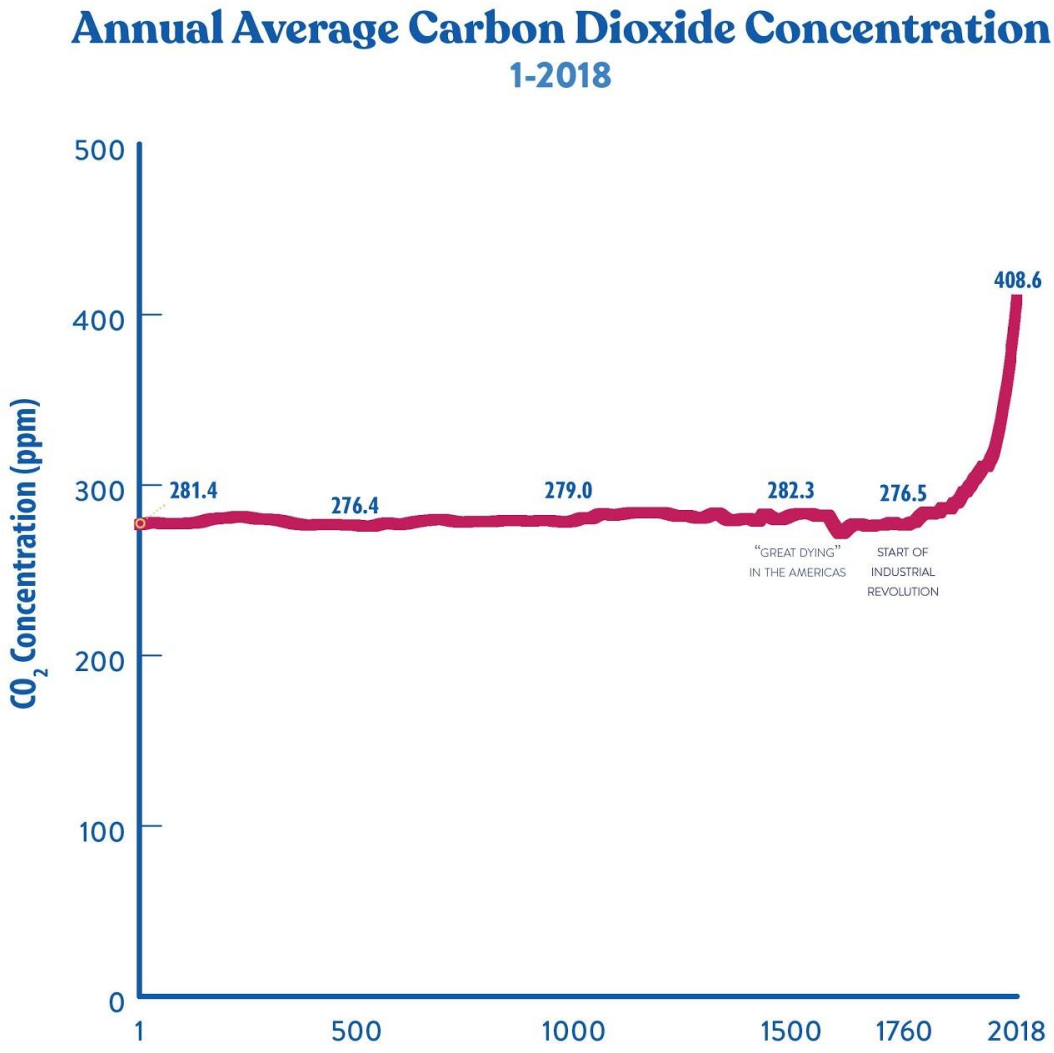
15,000 years ago - present: Everything that gets described as civilization--including the development of agriculture-- developed over the past 15,000 years, during a temperate period known as the Holocene, or “long summer” (Fagan, 2004). The concentration of energy in the form of food crops and animals (i.e., the Neolithic or Agricultural Revolution) provided sustenance that led to the development of settled, politically centralized, socially stratified, economically complex, technologically innovative societies in a few locations (Diamond, 1997).

For example, the Fertile Crescent region has the largest Mediterranean climate zone in the world, had 32 of the world’s best 56 wild grasses used for agriculture, and the wild ancestors of thirteen of the fourteen big animals domesticated before the twentieth century roamed Eurasia and nowhere else (these animals passed on diseases that Native Americans and Australians had no immunity to). These natural fortunes in turn led to the major agents of conquest described by Diamond–steel swords, guns, ocean-going ships, political organization, writing, and epidemic diseases–that enabled Europeans to conquerNative Americans, Africans, and Australian Aborigines. Although societal collapses in North and South America, Africa, and Australia due to climate change, resource depletion, and ecosystem degradation took place prior to European arrival, it was the original concentration of energy in the form of agriculture that enabled Europeans to introduce continent-wide collapse of indigenous populations in North America, South America, and Australia.

3,000 years ago - present: The starting date for the Anthropocene has not been pinpointed, with some suggesting the Agricultural Revolution, some pointing to the first atomic test, others to the mid-20th century. A new assessment by 250 archaeologists indicates that humans had fundamentally altered the planet by at least 3,000 years ago via hunting and gathering, farming, land clearing, grazing, and burning (Stephens et al., 2019).

Atmospheric carbon dioxide concentrations were flat for the majority of the past 2,000 years and only dramatically increased after the Industrial Revolution (1760).

1492 - 1610: The only dip in greenhouse gas concentrations in recent centuries occurred after the “Columbian Exchange,” when European colonists committed genocide and wiped out an estimated 90% of the indigenous population in the Americas. Reduced agricultural and land use activities meant that native plant species repopulated landscapes and, in turn, removed carbon from the atmosphere (Koch et al., 2019).



Sources: *Before 1958* - MacFarling Meure, C., D. Etheridge, C. Trudinger, P. Steele, R. Langenfelds, T. van Ommen, A. Smith, and J. Elkins. 2006. The Law Dome CO_2, CH_4 and N_2O Ice Core Records Extended to 2000 years BP. *Geophysical Research Letters*, Vol. 33, No. 14, L14810 10.1029/2006GL026152.

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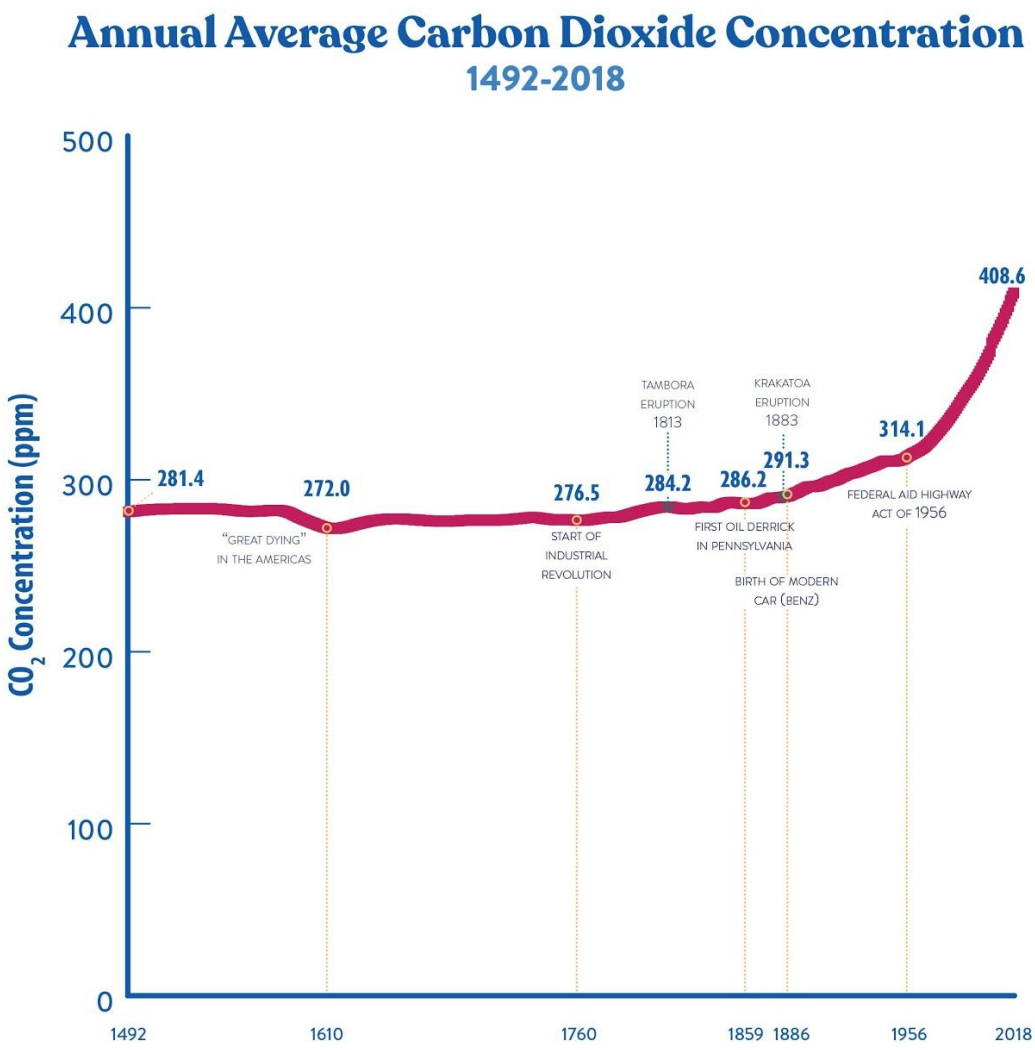

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Alexander Koch, Chris Brierley, Mark Maslin, and Simon Lewis, "Earth System Impacts of the European Arrival and Great Dying in the Americas After 1492," *Quarternary Science Reviews*, 207(1): 13-36, 2019, https://doi.org/10.1016/j.quascirev.2018.12.004.

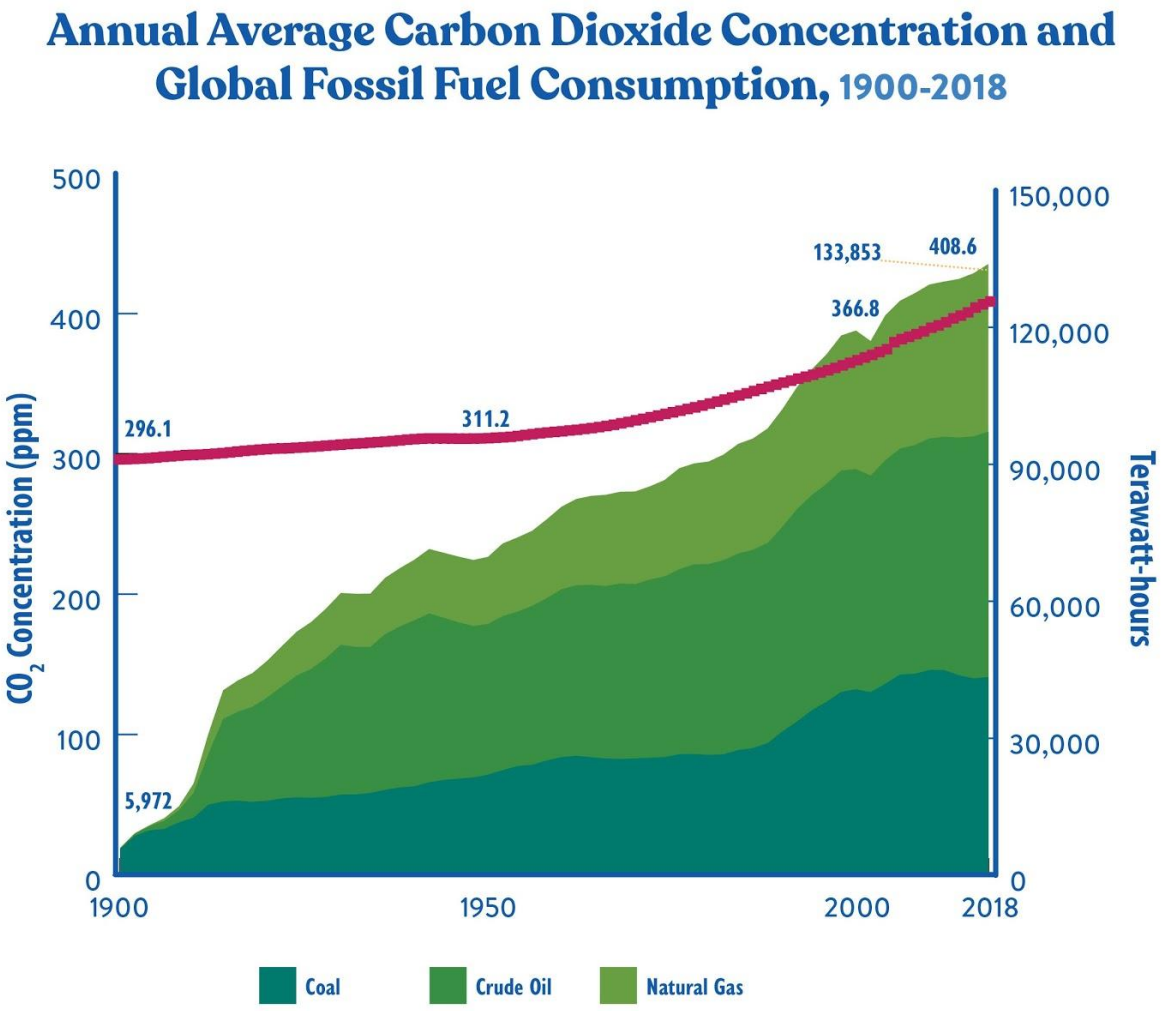
1760 - 1820 / 1840: the Industrial Revolution is generally described as starting around 1760 and refers to transitions from hand production to machine production, new chemical manufacturing and processes, increased use of steam power, water power, and coal. Major technological innovations in agriculture, including seed drills, iron ploughs, and threshing machines, were also developed.

1859: First drilling rig was used to drill for oil in Titusville, Pennsylvania. Every sector of the global economy, including agriculture, has been converted to fossil fuel--oil, natural gas, coal--dependency over the past 200 years.

1885: Karl Benz develops first gasoline powered automobile, deemed the birth of the modern car.

1896: Swedish scientist Svante Arrhenius calculated estimates of the extent to which increases in carbon dioxide can increase Earth's temperature through the greenhouse effect. This led him to conclude that anthropogenic emissions can be large enough to cause climate change (Christianson, 2000).

1901: With the Spindletop strike in Beaumont, Texas, the Age of Oil had begun (Yergin, 1991)



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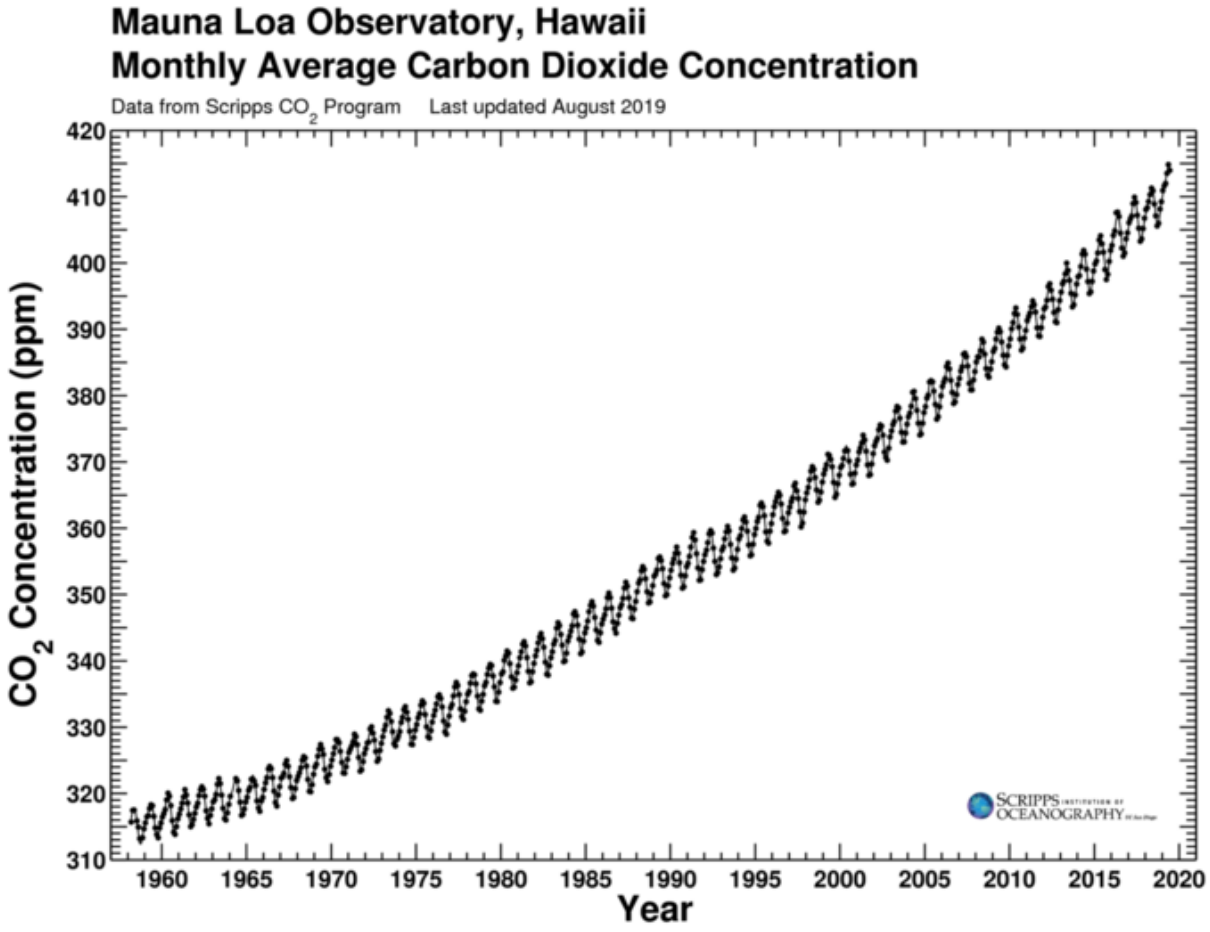
Global fossil fuel consumption: Vaclav Smil (2017). Energy Transitions: Global and National Perspectives. & BP Statistical Review of World Energy.

1908: Ford's Model T car is introduced. There are over 260 million passenger vehicles in the U.S. today.

1956: The Dwight D. Eisenhower National System of Interstate and Defense Highways (the Interstate Highway System) was authorized by the 1956 Federal Highway Act. The system was claimed completed in 1992 and the U.S. has at least 48,181 miles of interstate highways.

1958: Dr. Charles Keeling's measurements of atmospheric carbon dioxide concentration begin at the Mauna Loa Observatory in Hawaii. The "Keeling Curve" has measured seasonal variation

in atmospheric carbon dioxide concentration continuously since 1958 and about 100 sites around the planet now do the same. On May 9, 2013, atmospheric concentrations of carbon dioxide passed 400 parts per million, the first time levels have been this high in the past 2-4 million years (Montaigne, 2013).



1977: Exxon Corporation was devoting significant resources to understanding the risks posed by the accumulation of GHG in the atmosphere and oceans by at least 1977. (Banerjee et al., 2015; Jerving et al., 2015). Exxon then went on to spearhead the climate denial movement (Hasemyer and Cushman, Jr., 2015).

1979 - 1989: In this 10-year window covered by reporter Nathaniel Rich, nearly everything scientists understand about climate change was known, there was time to act, there were many stakeholders pushing for action, and the world almost acted on a binding climate change treaty in 1989. The U.S. government stopped this effort and *this was the decade we almost stopped climate change*. (Rich, 2018).

1988: In one of the first alarms for the general public, Dr. James Hansen testified before Congress about the risks posed by the greenhouse effect. The second Bush Administration subsequently attempted to censor the former head of NASA's Goddard Institute for Space Studies (Revkin, 2006).

1988: The Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations and World Meteorological Association to provide policymakers with regular scientific assessments of climate change. The IPCC is currently in its Sixth Assessment cycle.

1989: *The End of Nature* by Bill McKibben, dubbed the first book about climate change for a general audience, is published. McKibben later writes that our only hope is to fight climate change like we mobilized to fight World War II (McKibben, 2016).

1992, 1997, 2015: The United Nations Framework Convention on Climate Change, a treaty that sought to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" was signed by 197 countries, including the United States, at the Rio Earth Summit. Famously, the treaty had non-binding limits on GHG emissions and no enforcement mechanism.

1997: The Kyoto Protocol extends the United Nations Framework Convention on Climate Change by including binding GHG emissions reduction targets. However, although the United States is a signatory, it has not ratified the treaty.

2000-2018: The first National Climate Assessment, required by a 1990 law, is prepared by federal agencies in 2000. These detailed assessments cover regions of the US, sectors of the economy, and preparation, mitigation, and adaptation strategies. The first National Climate Assessment concludes that "It is likely that climate changes and atmospheric CO2 levels, as defined by scenarios in this assessment, will not imperil crop production in the US during the 21st century." (Page 380).

2006: The documentary *An Inconvenient Truth* by Vice President Al Gore received the Academy Award for Best Documentary Feature.

2006: California releases its First Climate Change Assessment. Regarding agriculture, an appendix to the assessment states: "California's cornucopia is predicated on its current climate and its supply and distribution of irrigation water; the latter is mainly derived from the snowpack on the surrounding Cascade and Sierra Nevada mountains, and is stored in dams and distributed via a network of aqueducts and canals. Unfortunately, current climate conditions in California are expected to change over the next 50 to 100 years."

2009: The second National Climate Assessment gives a more nuanced analysis of the impact of climate change on agriculture. For example, it notes that "Many crops show positive responses to elevated carbon dioxide and low levels of warming, but higher levels of warming often negatively affect growth and yields." And, "Increased heat, disease, and weather extremes are likely to reduce livestock productivity."

2009: California releases its Second Climate Change Assessment, including a separate paper on Climate Change-Related Impacts in the San Diego Region by 2050. Key issues explored in the report include potential inundation of six selected low-lying coastal areas due to sea level rise, potential shortfalls in water deliveries, peak energy demand increases due to higher temperatures, increasing risk of devastating wildfires, migrations of species in response to higher temperatures in an increasingly fragmented natural habitat, and public health issues associated with extreme temperature events.

2012: Two reports from the U.S. Department of Agriculture describe the anticipated detrimental effects of climate change on most crops, livestock, ecosystems, and human workers (these will vary by region):

- Rising temperatures and altered precipitation patterns will affect agricultural productivity. Crop sector impacts from weather in the U.S. are likely to be greatest in the Midwest, and these impacts will likely expand due to damage from crop pests. Moreover, since the impacts of climate change are global, the availability of food products that we have been accustomed to enjoying—and that American companies use as key ingredients—will diminish. For example, cocoa production in Ghana and the Ivory Coast is expected to decline, as is coffee production.
- Livestock production systems are major contributors to greenhouse gas emissions and are also vulnerable to temperature stresses. Temperature stresses can be mitigated for animals raised indoors, but hotter summer temperatures may require new thermal environment control systems and the cost and availability of animal feed will likely be a problem.
- Climate change will exacerbate current stresses from weeds, diseases, and insect pests on plants and animals; it will also alter pollinator life cycles, which will impact all types of crop and livestock production.
- Ecosystem services (e.g., flood control) that food systems depend on will be damaged. Increased incidences of extreme weather events will impact food production around the world.

Additionally, the possible human health effects of climate change are large, and farmers and farm workers will be especially impacted since they spend most of their days outside. These effects include:

- Injuries, illnesses, and deaths related to extreme heat and weather events.
- Infectious diseases related to changes in vector and zoonotic biology (e.g., Lyme disease) as well as risks from water and food contamination.
- Allergy and respiratory symptoms related to increasing plant and mold allergens and irritants in the air (US EPA).

2012: California releases its Third Climate Change Assessment. A study of agricultural vulnerability and adaptation to climate change explored a wider conceptual framework for climate change responses than has been addressed for California agriculture in the past. A "Total Agricultural Vulnerability Index" was created and predicts that the Central Valley, Salinas Valley, and southern counties are the most vulnerable to climate change. The results suggest that "there is a need for all agricultural communities to begin to develop adaptation plans that address the potential impact of changing climate, land use and economic factors."

2014: The Third National Climate Assessment was released in 2014. The key messages for agriculture are:

- climate disruptions to agricultural production have increased in the past 40 years and are projected to increase over the next 25 years. By mid-century and beyond, these impacts will be increasingly negative on most crops and livestock.
- Many agricultural regions will experience declines in crop and livestock production from increased stress due to weeds, diseases, insect pests, and other climate change induced stress.
- Current loss and degradation of critical agricultural soil and water assets due to increasing extremes in precipitation will continue to challenge both rainfed and irrigated agriculture unless innovative conservation methods are implemented.

- The rising incidence of weather extremes will have increasingly negative impacts on crops and livestock productivity because critical thresholds are already being exceeded.
- Agriculture has been able to adapt to recent changes in climate; however, increased innovation will be needed to ensure the rate of adaptation of agriculture and the associated socioeconomic system can keep pace with climate change over the next 25 years.
- Climate change effects on agriculture will have consequences for food security, both in the U.S. and globally, through changes in crop yields and food prices and effects on food processing, storage, transportation, and retailing. Adaptation measures can help delay and reduce some of these impacts.

2015: The Paris Agreement extends the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Each country must determine, plan, and regularly report on its efforts to mitigate climate change. Although President Obama entered the United States into the agreement through executive action, President Trump has said the U.S. would withdraw and has already taken actions to undermine our ability to prepare for, mitigate against, and adapt to climate change. However, the earliest date for U.S. withdrawal from the Paris Agreement is November 2020 and hopefully Trump will not be president at that point.

2017: The California Ocean Protection Council produces a report, Readying California Fisheries for Climate Change, that states:

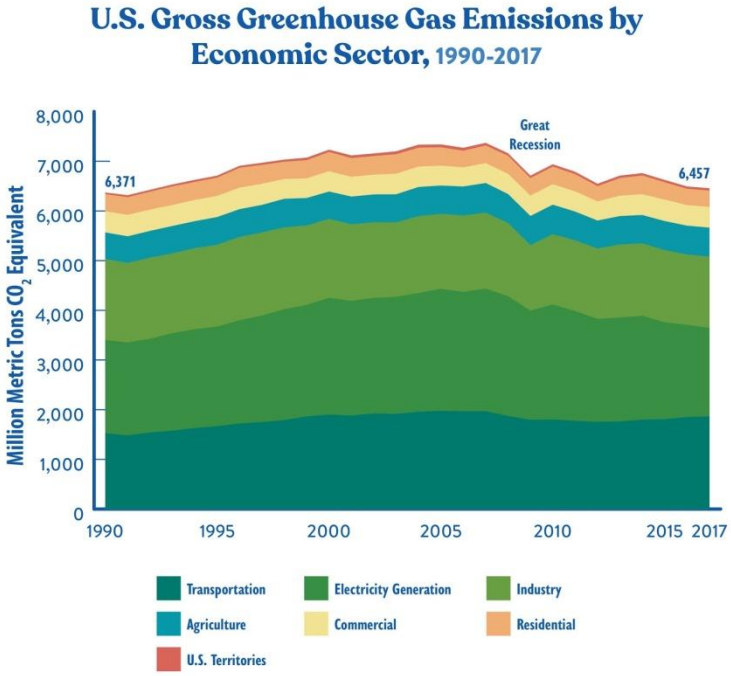
> *Climate change is already impacting California fisheries, affecting fish stocks and fishing communities. The physical changes associated with climate change (warming, ocean acidification, hypoxia, changes in circulation patterns, etc.) will continue to have both direct and indirect impacts on fish stocks. More extreme or variable environmental conditions are predicted to impact species' physiology, habitat availability, prey quality and abundance, species interactions, and/or other factors that influence population dynamics and sustainability of fish stocks. As a result, stock abundance and/or spatial distribution may increase or decrease, expand or contract, or simply become more variable. These changes will in-turn affect fishing communities.*
>
> *Direct impacts on fishing communities include increased storms or sea level rise and associated damage to fishing infrastructure and businesses. Indirect impacts could include changes in the abundance and/or distribution of fished species and may lead to human responses such as changes in fishing practices, which in turn can affect shoreside support infrastructure, goods, and services.*

2017: The fourth National Climate Assessment, released in 2017, concludes that "it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence." Regarding agriculture, the fourth assessment states:

> *Rising temperatures, extreme heat, drought, wildfire on rangelands, and heavy downpours are expected to increasingly disrupt agricultural productivity in the United States. Expected increases in challenges to livestock health, declines in crop yields and quality, and changes in extreme events in the United States and abroad threaten rural livelihoods, sustainable food security, and price stability.*

Four Key Messages were stated:

1. **Agricultural Productivity:** Food and forage production will decline in regions experiencing increased frequency and duration of drought. Shifting precipitation patterns, when associated with high temperatures, will intensify wildfires that reduce forage on rangelands, accelerate the depletion of water supplies for irrigation, and expand the distribution and incidence of pests and diseases for crops and livestock. Modern breeding approaches and the use of novel genes from crop wild relatives are being employed to develop higher-yielding, stress-tolerant crops.
2. **Degradation of Soil and Water Resources:** The degradation of critical soil and water resources will expand as extreme precipitation events increase across our agricultural landscape. Sustainable crop production is threatened by excessive runoff, leaching, and flooding, which results in soil erosion, degraded water quality in lakes and streams, and damage to rural community infrastructure. Management practices to restore soil structure and the hydrologic function of landscapes are essential for improving resilience to these challenges.
3. **Health Challenges to Rural Populations and Livestock:** Challenges to human and livestock health are growing due to the increased frequency and intensity of high temperature extremes. Extreme heat conditions contribute to heat exhaustion, heatstroke, and heart attacks in humans. Heat stress in livestock results in large economic losses for producers. Expanded health services in rural areas, heat-tolerant livestock, and improved design of confined animal housing are all important advances to minimize these challenges.
4. **Vulnerability and Adaptive Capacity of Rural Communities:** Residents in rural communities often have limited capacity to respond to climate change impacts, due to poverty and limitations in community resources. Communication, transportation, water, and sanitary infrastructure are vulnerable to disruption from climate stressors. Achieving social resilience to these challenges would require increases in local capacity to make adaptive improvements in shared community resources.

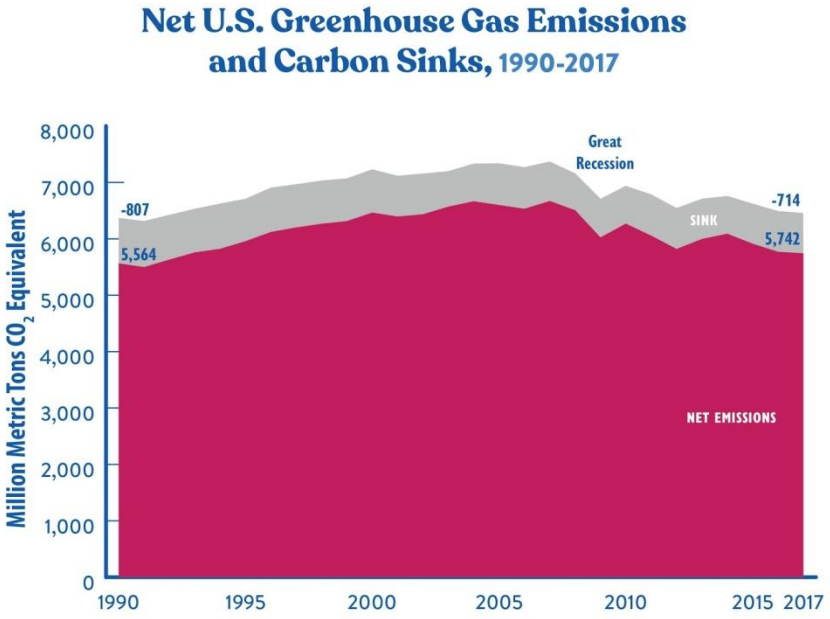


1990-2017: Total U.S. emissions increased 1.3% from 1990 to 2017. Emissions dropped during the Great Recession, a period of economic turmoil not experienced since the Great Depression. Agriculture accounted for 8% of U.S. GHG emissions.

From 1990 to 2017:

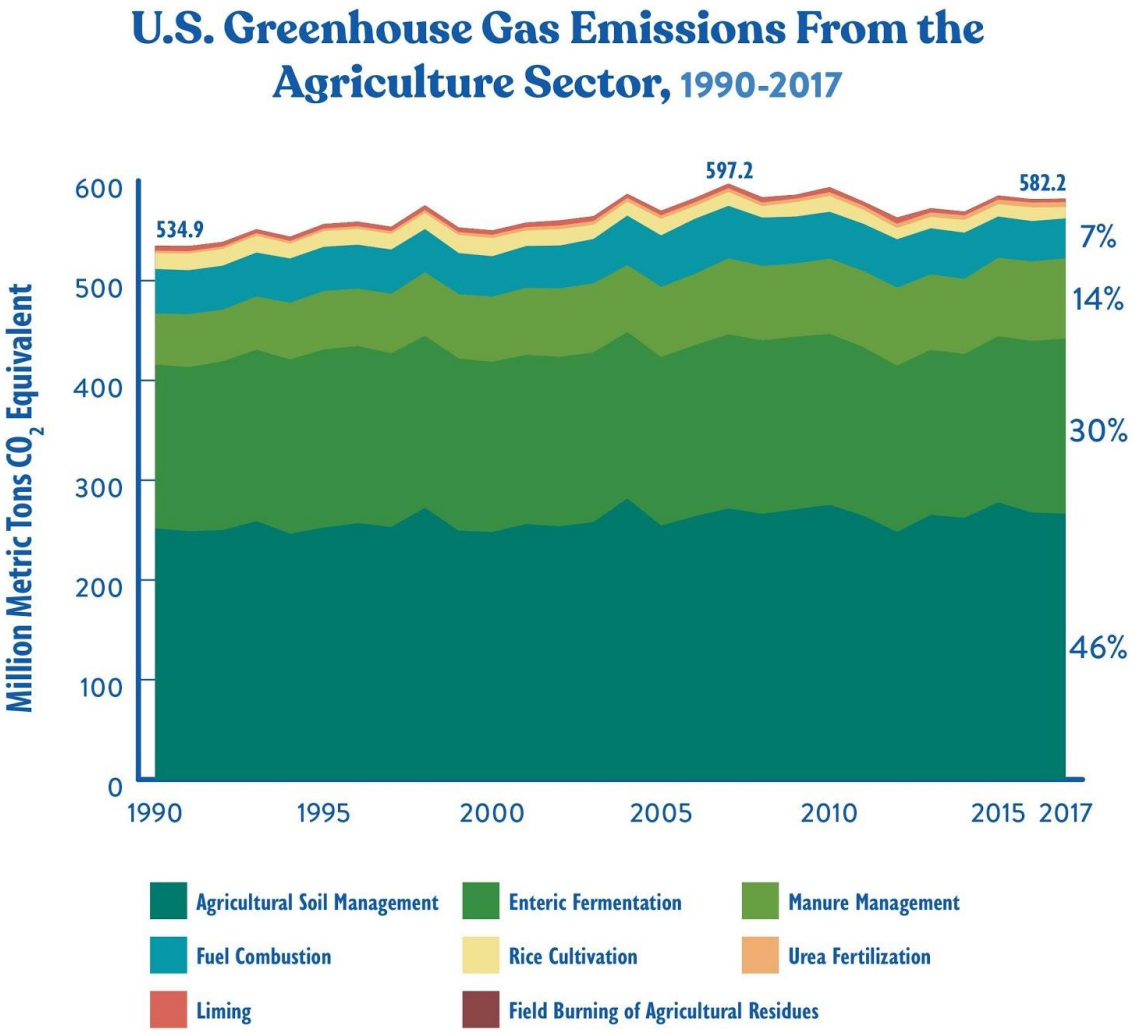
- Transportation: +22.2%
- Electricity Generation: -5.2%
- Industry: -11.8%
- Agriculture: +8.8%
- Commercial: -2.6%
- Residential: -4.0%

Forests accounted for 86% of American land-based carbon sinks. And carbon sinks are equivalent to 11% of gross GHG emissions.

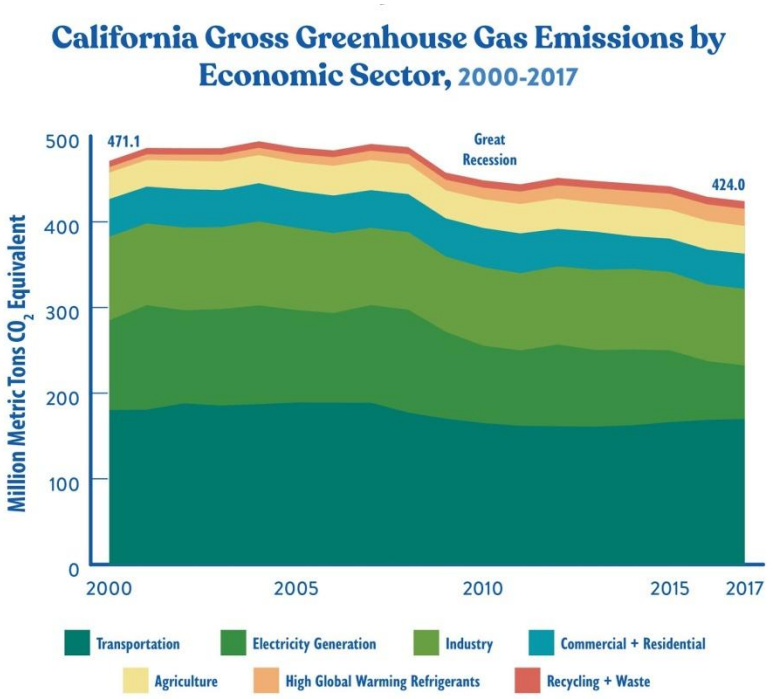


Emissions increased 9% for agricultural activities from 1990 to 2017:

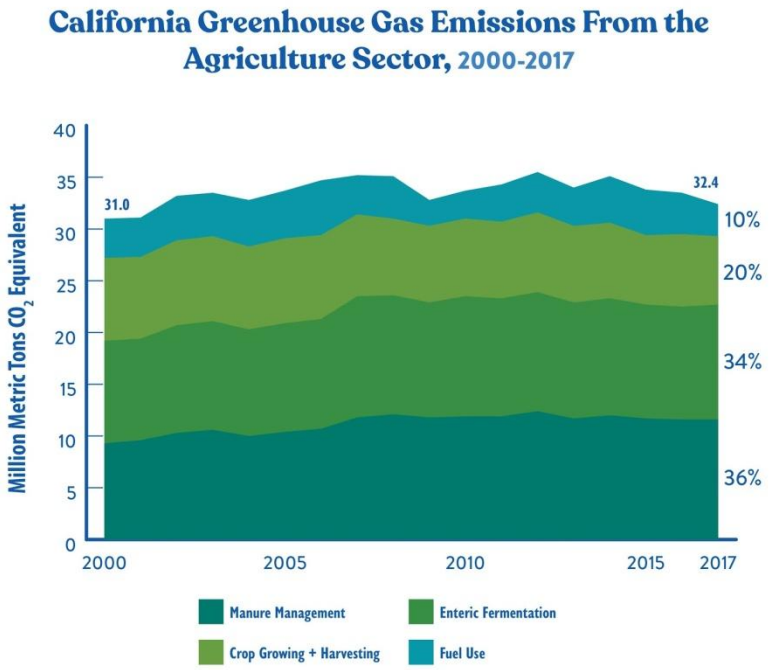
- Agricultural soil management: +5.8%
- Enteric fermentation: +6.9%
- Manure management: +57.1%
- Fuel combustion: -10%
- Rice cultivation: -29.2%
- Urea fertilization: +109.0%
- Liming: -31.8%
- Field burning of agricultural residues: 79.1%



2000-2017: California's GHG emissions decreased from 2000 to 2017, largely due to the increasing use of renewable energy to generate electricity. Agriculture accounts for 8% of California's GHG emissions. Livestock--via manure management and enteric fermentation--account for the majority of California agriculture's GHG emissions. Recall that Milk and Cream are the top agricultural commodity in California, equal to $6.5 billion in 2017.There were 3.1 million dairy cows in California in 2017.



Sources: California Air Resources Board (2019). California Greenhouse Gas Emission Inventory - 2019 Edition. https://ww3.arb.ca.gov/cc/inventory/data/data.htm



2018: California releases its Fourth Climate Change Assessment, warning of increasing temperatures, sea levels, heavy precipitation events, drought, wildfires, and decreasing snowpack. A study created for the Fourth Assessment suggests that climate-related crop losses will be less than impacts associated with the loss of water supply and conversion of agricultural lands to other uses.

The Fourth Assessment provides 9 regional assessments:

- San Diego
- Los Angeles
- Inland Deserts
- Central Coast
- San Joaquin Valley
- Sierra Nevada
- San Francisco Bay Area
- Sacramento Valley
- North Coast

And 3 categorical assessments:

- Climate Justice
- Tribal Communities
- Ocean and Coast Communities

2018: The first Special Report--Global Warming of 1.5 °C--of the Sixth Assessment cycle of IPCC reports was released in 2018. Stating that "Climate change represents an urgent and potentially irreversible threat to human societies and the planet," the report indicates that, given current trends, the Earth would reach warming of 1.5°C (2.7°F) by 2040. This is the red line that scientists have warned about that may intensify droughts, wildfires, glacial melt, food shortages, and so on, and it's only 21 years away (we may reach 1.5°C as early as 2030).

2019: The second Special Report--Climate Change and Land--of the Sixth Assessment cycle of IPCC reports was released in 2019. The report concludes that human use directly affects more than 70% of the global, ice-free land surface. This is unprecedented in human history. Confidence is very high that the window of opportunity, the period when significant change can be made, for limiting climate change within tolerable boundaries is rapidly narrowing. One of the lead authors, Cynthia Rosenzweig, is quoted in the New York Times as saying "The potential risk of multi-breadbasket failure is increasing. All of these things are happening at the same time." (Flavelle, 2019).

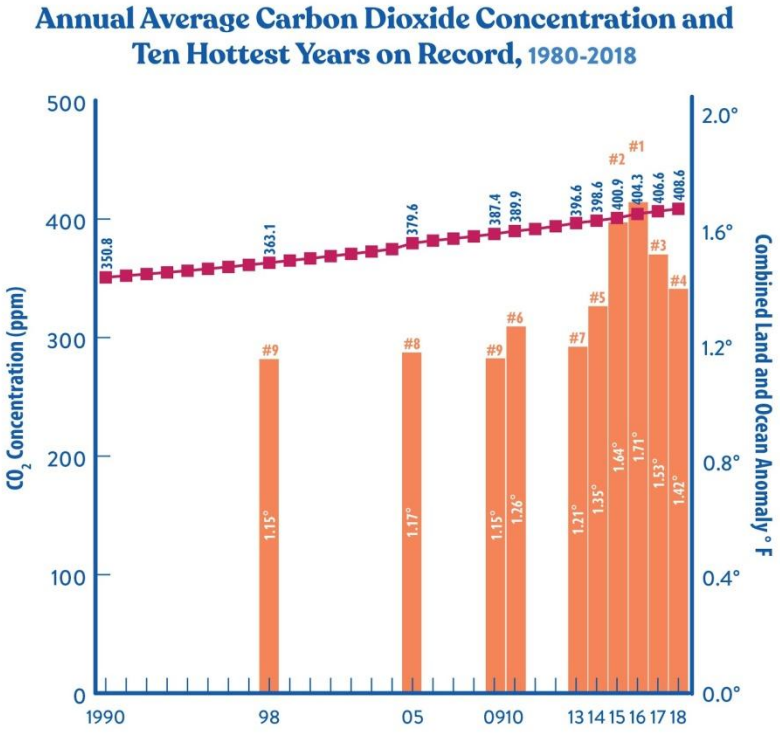
The largest companies by revenue in the world are intimately connected to continued dependence on fossil fuels, cheap goods (including food), and automobility.

Name	Industry	Revenue	Profit
1 Walmart	Retail	$514,405,000,000	$6,670,000,000
2 Sinopec (China)	Oil and Gas	$414,649,000,000	$5,845,000,000
3 Royal Dutch Shell (Netherlands/UK)	Oil and Gas	$396,556,000,000	$23,352,000,000
4 China National Petroleum	Oil and Gas	$569,696,000,000	$2,270,000,000
5 State Grid (China)	Electricity	$387,056,000,000	$8,174,000,000

6 Saudi Aramco	Oil and Gas	$355,905,000,000	$110,974,000,000
7 BP	Oil and Gas	$303,738,000,000	$9,383,000,000
8 ExxonMobil	Oil and Gas	$290,212,000,000	$20,840,000,000
9 Volkswagen	Automotive	$278,341,000,000	$14,332,000,000
10 Toyota	Automotive	$272,612,000,000	$16,982,000,000

1980 - 2019: From 1980–2019 (as of July 9, 2019), there have been 26 drought events, 31 flooding events, 9 freeze events, 109 severe storm events, 42 tropical cyclone events, 16 wildfire events, and 17 winter storm events with losses *exceeding* $1 billion (CPI-Adjusted) each across the United States, for a total cost that exceeds **$1.7 trillion**. Texas leads the way with 106 disasters, and disasters are more common across the South. **California had 36 disasters that exceeded $1 billion each, including 11 drought events and 14 wildfires** (NOAA, 2019).

1998-2019: Ten of the warmest years on record--as measured by global combined land and ocean annual averages--have just happened.



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NOAA, Global Climate Report, https://www.ncdc.noaa.gov/sotc/global/201713.

2019: Climate change impacts on food systems are evident all over the world (Severson, 2019).

A Washington Post analysis of multiple temperature data sets found numerous locations around the globe that have warmed by at least 3.6 degrees Fahrenheit (2 degrees Celsius) over the past century. That's a number that scientists and policymakers have identified as a red line if the planet is to avoid catastrophic and irreversible consequences. But in regions large and small, that point has already been reached (Mooney and Muyskens, 2019).

6 IPCC Assessments
4 National Assessments
4 California Assessments
1,000s of articles

Modern societies are more technologically sophisticated, historically aware, scientifically knowledgeable, and interconnected than ever before. Despite accumulated evidence of the risk, greenhouse gas emissions continue to build up and climate change is getting worse.

"Long-term disaster is now the best-case scenario." (Rich, 2018)

Current:

The Green New Deal, introduced by Representative Alexandria Ocasio-Cortez of New York and Senator Edward J. Markey of Massachusetts, calls for meeting 100% of America's power demand through renewables, upgrading all existing buildings, investing in clean manufacturing, transforming our transportation system, and removing pollution and GHG emissions from agriculture. The agricultural goals for the Green New Deal resolution are vaguely stated as:

- Supporting family farming
- Investing in sustainable farming and land use practices that increase soil health
- Building a more sustainable food system that ensures universal access to health food.

Commentators view this approach as going straight to the public to solicit solutions from the ground up, rather than through corporate interests (Philpott, 2019). There is no timeframe for

adoption of the Green New Deal. The Republican Party is wholly in opposition, while several Democratic candidates for President have come out with their own versions.

Now: Project Drawdown describes 100 solutions for addressing reducing greenhouse gas emissions, including at least 21 solutions that have to do with food systems. These 21 solutions would hypothetically account for 32.5% of GHG drawdown.

Project Drawdown Food System Solutions

SOLUTION	TOTAL ATMOSPHERIC CO_2 EQUIVALENT REDUCTION (GT)	PERCENT OF TOTAL CO_2
3 Reduced Food Waste	70.53	6.8%
4 Plant-Rich Diet	66.11	6.4%
9 Silvopasture	31.19	3.0%
11 Regenerative Agriculture	23.15	2.2%
14 Tropical Staple Trees	20.19	2.0%
16 Conservation Agriculture	17.35	1.7%
17 Tree Intercropping	17.20	1.7%
19 Managed Grazing	16.34	1.6%
21 Clean Cookstoves	15.81	1.5%
23 Farmland Restoration	14.08	1.4%
24 Improved Riceland Cultivation	11.34	1.1%
28 Multistrata Agriculture	9.28	0.9%
30 Methane Digesters (large)	8.40	0.8%
53 System of Rice Intensification	3.13	0.3%
58 Landfill Methane	2.50	0.2%
60 Composting	2.28	0.2%
64 Methane Digesters (small)	1.90	0.2%
65 Nutrient Management	1.81	0.2%
67 Farmland Irrigation	1.33	0.1%
68 Waste-to-Energy	1.10	0.1%
72 Biochar	0.81	0.1%
FOOD SYSTEM SUBTOTAL	**335.83**	**32.5%**
ALL SOLUTIONS TOTAL	**1034.75**	**100.0%**

A gigaton is equal to 1 billion metric tons.

Regions, states, and cities have tried to fill the void left by U.S. federal government inaction.

California

- **ENERGY:** The state of California adopted a Renewables Portfolio Standard that requires "load-serving entities" to increase their procurement of renewable electricity to 33% of retail sales by 2020 and 60% of retail sales by 2030. California is currently at 34% renewable electricity, so slightly ahead of schedule.
- **EMISSIONS:** The state of California has set a goal of reducing GHG emissions to 1990 levels by 2020 and 80% below 1990 levels by 2050 (AB 32).
- Climate Action Plans: San Diego County

Now: Greta Thunberg starts “School Strike for Climate” and galvanizes youth-led response to climate change.

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