What is a Fair Carbon Budget for the United States?

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June 22, 2022

Abstract

When most people think about the US's responsibility for helping the world limit the global temperature increase to 1.5°C they probably assume that all the US has to do is to follow a "net-zero in 2050" emissions pathway. What is usually missing from the discussions is that greenhouse gas emissions are a global problem and a globally equitable approach is required. As a very rich country that has a very high standard of living, we are not in a position to deny developing countries the right to significantly increase their standards of living to something more comparable to ours (i.e., "carbon footprints" in an equitable world would be about the same for all citizens). Determining a fair carbon budget for the United States should be a straight forward process:

1. Determine a range of equitable emissions pathways for all countries
2. Specify a carbon budget
3. Since the sum of emissions from the equitable pathways will exceed the carbon budget, devise an equitable process for allocating responsibilities for dealing with the overage

Table 1 shows the US's responsibility for removing CO2 from the atmosphere to meet the carbon budget for 66% chance of limiting the temperature increase to 1.5°C for a number of emissions pathways. The table shows that, even if all countries in the world were to meet the emissions of a "net zero in 2050 pathway", the US should be responsible for removing all of its future emissions.

2. Probability	**1. Net Cumulative Emissions 2020-2100**										
	660	**800**	**1050**	**1300**	**1500**	**1700**	**1750**	**2000**	**2300**	**2600**	**2900**
50%	1.59	1.68	1.82	1.97	2.09	2.21	2.24	2.38	2.56	2.74	2.91
67%	1.68	1.77	1.94	2.10	2.24	2.37	2.41	2.57	2.77	2.98	3.18
83%	1.79	1.91	2.12	2.33	2.49	2.66	2.70	2.91	3.16	3.40	3.65
3. CDR: 1.5°C /67%	260	400	650	900	1100	1300	1350	1600	1900	2200	2500
4. US CDR Resp. at 25%	92	100	163	225	275	325	338	400	475	550	625
Cost at $100/Ton (Trillions)	9	10	16	23	28	33	34	40	48	55	63
Cost/year at $100/Ton (Billions)	184	200	325	450	550	650	675	800	950	1100	1250
Cost/household/year	1147	1250	2031	2813	3438	4063	4219	5000	5938	6875	7813
5. Pathways	**Global Net Zero 2050**		**CAT: Optimistic**		**CAT: Pledges and Targets**		**CAT: Targets Only**		**CAT: Policy and Action**		
			1338		**1680**		**2041**		**2865**		

1. Cumulative Emissions 2020-2100 - Range of possible values. 2019 Carbon dioxide (CO_2) emissions from the burning of fossil fuels for energy and cement production were about 36.7 GT CO2 (https://ourworldindata.org/search?q=CO2) and average emissions from land use changes from 2014 to 2020 were about 3.9 GT CO2 (https://ourworldindata.org/grapher/global-co2-emissions-fossil-land) for a total of about 40.6 GT CO2. Emissions for 2020 and 2021 were slightly less than those in 2019, so if emissions decrease linearly from 40 GT CO2 at the start of 2022 to 0 at the end of 2050, total net emissions would be about 660 GTCO2 (first column). Gross emissions would be about 900 GTGCO2, total CDR about 500 GTCO2, and CDR to be allocated among countries about 260 GTCO2

2. Probability – the numbers to the right of the three IPCC carbon budget probabilities are the resulting temperature increase in 2100 based on the indicated net cumulative CO2 emissions from 2020-2100

3. CDR: 1.5°C /67% - Global carbon dioxide removal requirement based on a carbon budget of 400 GT CO2 (500 = cumulative emissions – 400); 240 GTCO2 would be sequestered as part of each country "net zero pathway" and 260 GTC O2 would be allocated to individual countries on an "ability to pay" basis

4. US Resp. at 25% - The amount of CO2 that the US would be responsible for if the US were responsible for 25% of the CO2 removal that would be required for a 400 GT CO2 carbon budget. For the "Global Net Zero 2050" it includes 27 GT CO2 for the US's "net zero in 2050 pathway" plus 25% of the CDR required if every country follows a "net zero in 2050 pathway" (92=27 + 25% *260 GTCO2) (Note that US cumulative emissions on a "net zero in 2050" pathway would be about 94 GT CO2)(Note: Of the countries expected to pay for CDR, the US is responsible for over 27% of historical emissions and had over 27% of the global GDP in 2020.) For the CAT pathways the US's CDR requirement is 25% of the total CDR requirement. "Cost/year at $100/Ton (Billions)" is the average cost over 50 years. "Cost/household/year" assumes 160 million households.

5. Pathways -CAT = "Climate Action Tracker" (where CO2 emissions = 70% of greenhouse gas emissions). These are the four pathways for which CAT estimated annual GHG emissions based on each country's NDC. Colored cells indicate the CO2 emissions for the indicated pathway. Note that the "Global Net Zero 2050" pathway includes negative emissions of 260 GTCO2 and gross emissions of 900 GTCO2.

Table 1. US Carbon Dioxide Removal Requirement for 66% Chance of Limiting the Temperature Increase to 1.5°C

Analysis

Since future greenhouse gas emissions will exceed the carbon budget for 1.5°C, significant quantities of CO2 will need to be removed from the atmosphere in order to limit the temperature increase to 1.5°C in the year 2100 (see Figure 1 for an example of the quantities involved). As a country both responsible for about 25% of historical greenhouse gas emissions and also one of the richest, the US has a unique role to play in helping to limit to the future temperature increase.

CO2Budget: 400 GT CO2[1]	CO2 Emissions (2020-2100): 1,680 GT CO2[2]
CO2 Removal: 1,280 GT CO2[3]	

1. IPCC CO2 budget for 67% chance of the temperature increase not exceeding 1.5°C
2. Climate Action Tracker "Pledges and Targets Scenario" cumulative GHG emissions * 70% (to estimate CO2 emissions)
3. CO2 Emissions – Carbon Budget

Figure 1 – Example of Global CO2 Budget, Emissions, and Removals

In order to determine a fair carbon budget for the US we need to first choose a global carbon budget (See Appendix A). Based on the recent IPCC AR6 report[1] and the assumption that we need to limit the temperature increase to 1.5°C, the "2020-2100" CO2 budget is about 400 GTCO2[1] (note that this might need to be adjusted as more information on natural feedbacks becomes available).

Next, we need to estimate gross global CO2 emissions for 2020 through 2100 so that we can estimate the global CO2 removal requirement. Using a simplified emissions pathway (see Appendix B), the gross CO2 emissions for 2020-2100 can be estimated as 882 GTCO2 if all countries are able to achieve "net zero emissions" in 2050. Since most countries are not expected meet their emissions forecasts specified in their NDC's, a more realistic emissions pathway for planning purposes is Carbon Action Tracker's "Pledges and Targets Scenario", which results in cumulative greenhouse gas emissions of about 2,346 GCTCO2e (or 1,876 GTCO2 if 80% of the GHG emissions are due to CO2).

		Net Zero in 2050[1]	Carbon Action Tracker "Pledges and Targets Scenario"[2]
1	2019 global CO2 emissions (fossil fuels and land use)	42	42
2	CO2 Budget	400	400
3	Estimated Gross global CO2 emissions	881	1680
4	Estimated CO2 removal as a part of the pathway	252	207
5	Estimated Net CO2 (#3 –#4)	629	1473
6	Estimated over budget (CDR to be allocated) (#5 - #2)	229	1273
7	Estimated total CDR requirement (#4 + #6)	481	1480

Table 1. Estimating the Global Gross CO2 emissions and the CDR removal requirement

1. Values from Table B1 in Appendix B
2. Values from Table B2 in Appendix B

Note: if actual emissions declined linearly from 42 GTCCO2 oi 2022 to 0 in 2050, the total emissions would be about 630 GTCO2

Then to estimate the US carbon budget we need to estimate the amount of the GTCO2 overage for which the US should be responsible. If the US should be responsible for about 25% of the overage (see Table 3), then the US would be responsible for an additional 56 GTCO2 for a "net zero" pathway, leaving a carbon budget of about 10 GTCO2 (see Table 4). And if emissions were closer to 1900 GT CO2 (an example of allowing for the less developed counties to have a fair reduction pathway), the US budget would be about -250 GT CO2.

1	US Percentage of cumulative CO2 emissions	25.5
2	US Percentage of annual GDP (2020)	25.0
3	Average of the above	25

Table 3. Estimating the US Responsibility for CDR

		Net Zero in 2050[1]	Carbon Action Tracker "Pledges and Targets Scenario"[2]
1	Estimated over budget (CDR to be allocated)	229	1270
2	US Responsibility of overage	57	318
3	US CDR in a "net zero in 2050 pathway"[3]	27	27
4	Total US CDR responsibility	84	345
5	US Gross emissions in a "net zero in 2050 pathway[3]	95	95
6	US CO2 post 2020 budget	11	-250

Table 4. Estimating the US CO2 Budget

A US CO2 budget that takes into account the abilities and desires of the less-developed countries can be estimated as follows:

- Divide the world's countries into nine groups, with four of the groups based on the World Banks "GNI" index of income levels:

  - China
  - United Sates
  - European Union
  - India
  - Annex I countries (supposed to help other countries mitigate emissions)
  - GNI Index
  - Upper
  - High
  - Medium
  - Lower
- For each group estimate CO2 and GHG emissions, GDP, and population, emissions growth rate
- For each group specify:
  - CDR Percent - the percent of their CDR requirement from their "net-zero pathway" that they are responsible for (e.g., the US is responsible for 100%, while least developed countries might not be responsible for any)
  - Number of years of growth – less developed countries should be able to grow (e.g., India's NDC call for 15 year of growth – see Appendix C)
  - Number of years where emissions remain the same ("plateau") (e.g., China's NDC calls for 10 years of no emissions change – see Appendix B)
  - Number years to net-zero- 30 years is a good estimate for all countries
- Determine what factors to take into account when assigning responsibility for removing atmospheric COP2 to meet the global CO2 budget (e.g., emissions, GDP, population).

The web page at "Fair Allocations" (https://www.fairallocation.org/Allocations.aspx) provides a tool that does all of the calculations needed to estimate a carbon budgets for the nine groups listed above. Table 4 shows the results for a global pathway (for 1.5°C) that allows less developed countries to continue their current emission trajectories for 5-20 years. Note that in this case the US budget is -261 GTCO2 for a 1.5°c temperature target. Note also that the net emissions here are about those of a 2.15°C budget and that the US would still be responsible for removing almost twice its post-2020 emissions (See Table 5). (Table 6 shows the results for the "all countries net-zero in 2050" pathway.)

Appendix A. The CO2 budget

1. The IPCC CO2 Budget[1]

Approximate global warming relative to 1850–1900 until temperature limit (°C)*(1)	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) Likelihood of limiting global warming to temperature limit*(2)					Variations in reductions in non-CO_2 emissions*(3)
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

a. Issues

i. What value for "non-CO2" emissions was used for the carbon budget estimates, and are only anthropogenic "non-CO2" emissions considered? (needed so the budget can be adjusted for various forecasts of "non-CO2" emissions)

ii. Is the budget for just anthropogenic CO2 emissions?

iii. What CO2e value was used for emissions-equivalents from natural feedbacks? (needed so the budget can be adjusted for various forecasts of emissions-equivalents from natural feedbacks)

2. Emissions-equivalents from natural feedbacks

This chart was developed in 2015 – it needs to be updated
(source: http://ccdatacenter.org/documents/GlobalWarmingFeedbacks.pdf)

Feedback	Maximum Potential Radiative Forcing	Likely Change 1870 - 2100			
Albedo Changes		Radiative Forcing	Total Equiv. Emissions	Atmos. CO2e Change (PPM)	Temp Incr.
Arctic Ocean[1]	0.76	0.39	452	26.1	0.20
Retreating snowline[2]	0.69	0.31	409	23.6	0.16
Tundra greening[3]					
Land use changes[3]					
Other? [3]					
GHG Emissions	Carbon Store Size				
Permafrost [2a]	6,230–6,780[4] 3,660[5]	.33	440*	25.5	0.19
Peatlands and Peat Bogs[6]	2000[7,8]	.30	400*	23.1	0.17
Methane Hydrates[3]	5000 to 36000[4]				
Reservoirs		0.05	60	3.5	0.10
Other Soils[3]					
Amazon[3]	315				
Temperate Forests[3]					
Other? [3]					
Total		1.38	1761	101.8	0.84*

3. CO_2 budget for planning purposes
   a. Temperature increase target: 1.5°C
      i. The 2°C was suggested by Nordhaus over 20 years ago using a "linear damage function" for impact of temperatures on GDP
      ii. Recent analysis predicts "severe consequences" if the temperature remains over 1.5°C for an extended period of time
   b. Probability – 67%
      i. Many analyses use 50%, but considering the possible consequences of being wrong a much higher number should be used (particularly considering the fact that IPCC estimates are very conservative)
   c. Post-2019 carbon budget – 400 $GTCO_2$
   d. Post-2022 carbon budget – 276 $GTCO_2$
      i. probably needs to be adjusted based on emissions-equivalents from natural feedbacks

Appendix B – Simplified Emissions Pathway and Cumulative Estimation Factor

Simplified Emissions Pathway

- Emissions increase a specific amount each year for set number of years
- Emissions remain constant for set number of years
- Emissions decrease linearly to zero in a set number of years

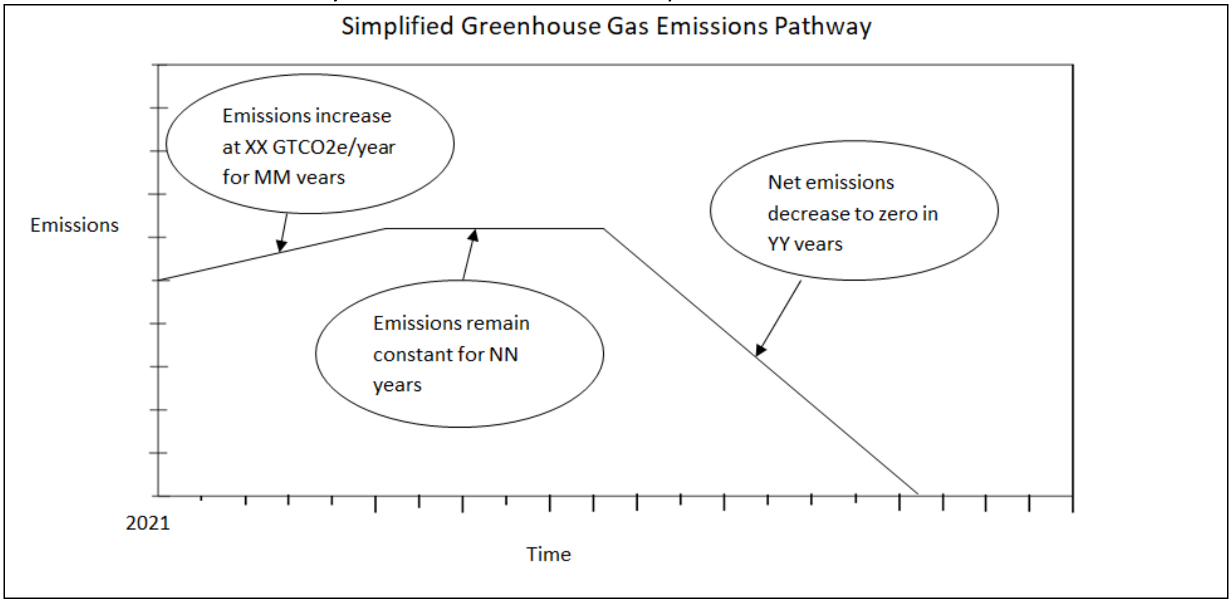
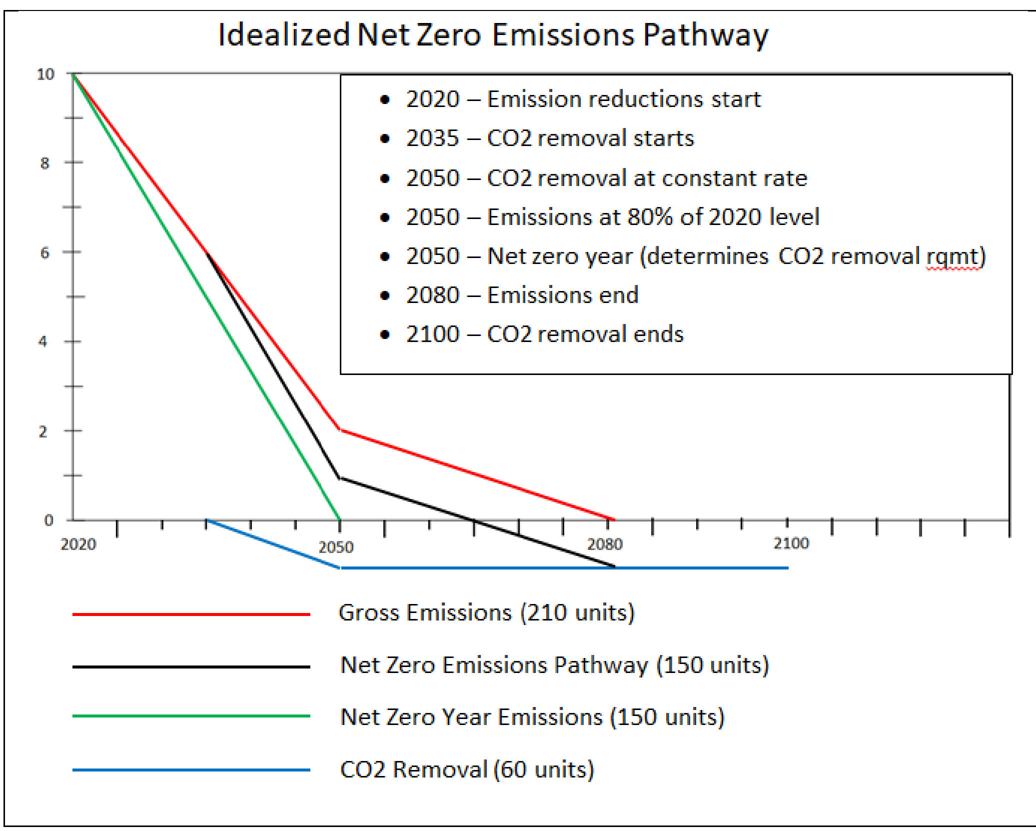


Figure B1. Expected Future Emissions – Estimating Emissions after a Peak Year to a "Net Zero" Year

Idealized Net-Zero Pathway



The "Cumulative Estimation Factor" is the number by which "emissions at the start of net zero" is multiplied by to estimate the total gross emissions:

Cumulative Estimation Factor
=
Emissions in First Year/Number of years
=
210/10
=
21

Figure B2 – Idealized Net-Zero Emissions Pathway

Emissions and allocations if all countries follow the "net zero in 2050" pathway

2019 Carbon dioxide (CO_2) emissions from the burning of fossil fuels for energy and cement production were about 36.7 GT CO2 (https://ourworldindata.org/search?q=CO2) and average emissions from and use changes from 2014 to 2020 were about 3.9 GT CO2 https://ourworldindata.org/grapher/global-co2-emissions-fossil-land) for a total of about 40.6 GT CO2. Emissions for 2020 and 2021 were slightly less than those in 2019, so if emissions decrease linearly from 40 GT CO2 at the start of 2022 to 0 at the end of 2050, total net emissions would be about 660 GTCO2

The "Allocate Global CO2 and CDR Budget" Web page at the Website "Fair CDR Allocation" (http://fairallocation.org/Allocations.aspx) was used to set both the "Years of Growth" and "Years of Plateau" values to zero and then adjusted slightly so that the cumulative net emissions were about 660 GTCO2 (see Table B1).

Country	Carbon (CO2) Budget Specifications												
	Resp. Pct.	CDR Percent	#Years Grwth	#Years Plat.	#Years NetZer	Pathway CO2 Emiss.				Fair Alloc			
						Annual	Cum	CDR	Net	Alloc	CDR	CDR$	Budget
China	13.66	100	0	0	30	8.52	179	51	128	35	86	10.75	93
United States	25.48	100	0	0	30	4.70	99	28	70	65	93	11.67	6
European Union	22.66	100	0	0	30	2.67	56	16	40	58	74	9.26	-17
India	3.23	100	5	0	25	2.77	63	17	47	8	25	3.16	38
World - Annex I	18.61	100	0	0	30	3.44	72	21	52	48	69	8.59	3
World - High	2.88	100	0	0	30	1.51	32	9	23	7	16	2.05	16
World - Upper	9.54	100	0	0	30	10.31	217	62	155	24	86	10.81	131
World - Medium	2.91	100	5	0	25	4.89	110	29	80	7	36	4.56	74
World - Lower	1.04	100	5	0	25	3.79	85	23	62	3	26	3.21	59
Total	100.00					42.62	912	256	656	256	512	64.06	401

(Note: 'World' totals do not include the individidual countries listed above.)

Table B1. Emissions and allocations if all countries follow the "net zero in 2050" pathway

Methodology used to calculate the CO2 emissions for Climate Action Tracker's "Pledges and Targets Scenario"

The data from Figure B2 ("Climate Action Tracker 2100 Warming Projections") were used to estimate the cumulative greenhouse gas emissions for 2020-2100 for the four scenarios. These totals were multiplied by 80% to estimate the cumulative CO2 emissions (use in the IPCC budget calculations). Thus, the cumulative CO2 emissions for the "Pledges and Targets" scenario are about 1,876 GTCO2. The "Allocate Global CO2 and CDR Budget" Web page at the Website "Fair CDR Allocation" (http://fairallocation.org/Allocations.aspx) was used to adjust the "Years of Growth" and "Years of Plateau" such that cumulate emissions were close to 1,876 GTCO2. Note that both the US and EU have "net zero in 2050" pathways specified.

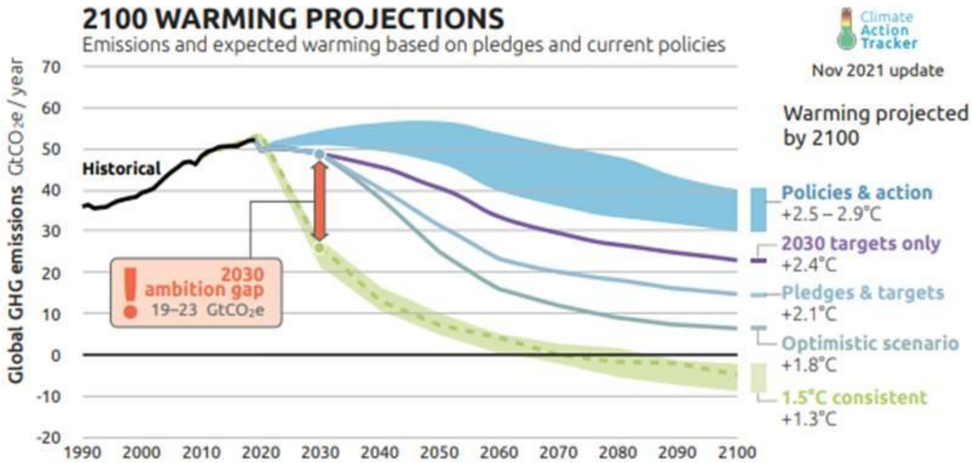


Figure 2 Global greenhouse gas emission pathways for CAT estimates of policies and action, 2030 targets only, 2030 and binding long-term targets and an optimistic pathway based on net zero targets of over 140 countries in comparison to a 1.5°C consistent pathway.

https://climateactiontracker.org/global/temperatures/

Figure B2. **Climate Action Tracker 2100 Warming Projections**

Scenario	GHG Emissions (GTCO2e)										CO2
	2020	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**	**2020-2100**	**80% of GHG**
Policy and Action	50	52	53	55	53	51	49	47	45	4043	3234
Targets Only	50	50	45	40	35	32	28	24	20	2885	2308
Pledges and Targets	50	50	41	32	23	21	19	17	14	2345	1876
Optimistic	50	50	37	24	11	10	9	8	6	1765	1412

Table B2. Annual and Cumulative emissions for Climate Action Tracker's four scenarios

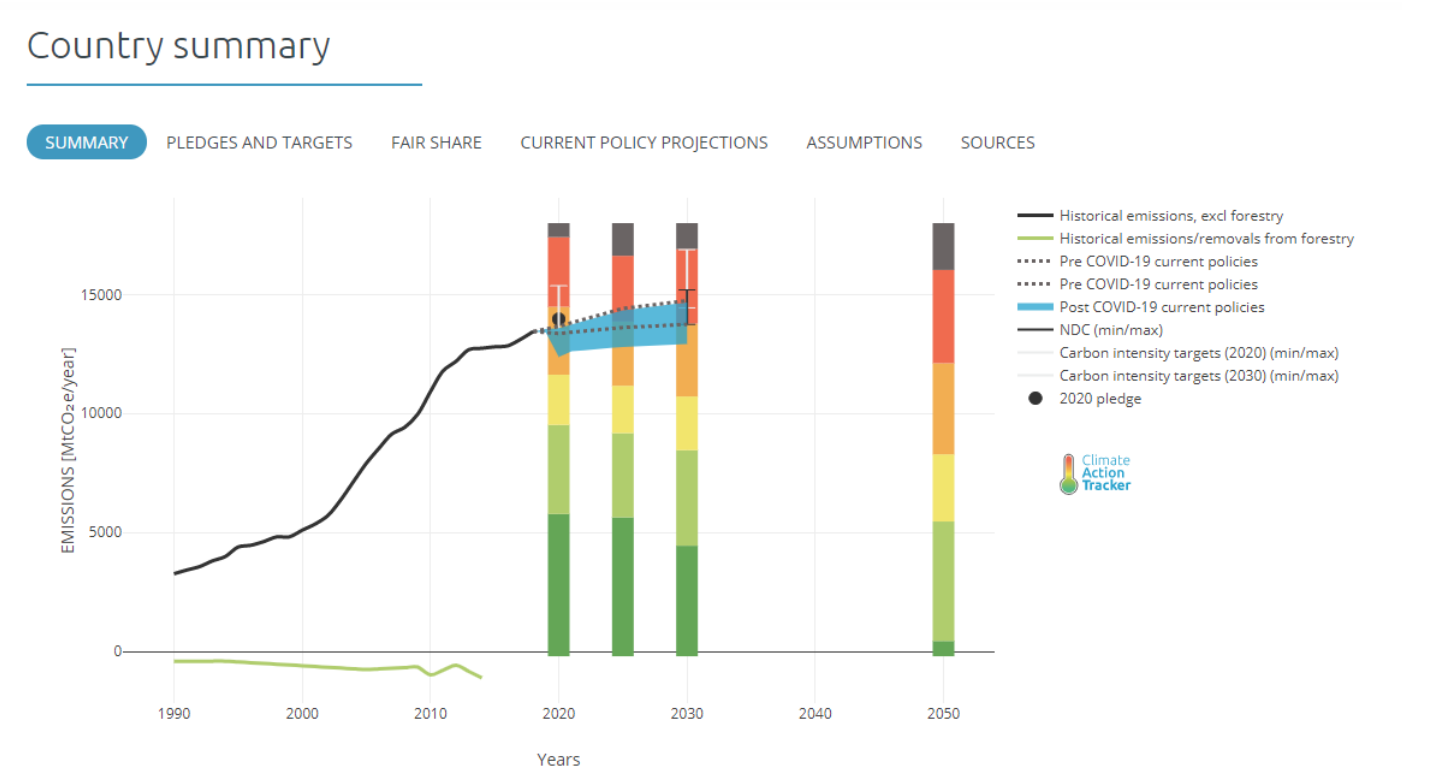
Country	Carbon (CO2) Budget Specifications												
	Resp. Pct.	CDR Percent	#Years Grwth	#Years Plat.	#Years NetZer	Pathway CO2 Emiss.				Fair Alloc			
						Annual	Cum	CDR	Net	Alloc	CDR	CDR$	Budget
China	14.93	100	10	0	30	8.07	249	48	200	190	238	29.71	11
United States	27.86	100	0	0	30	4.44	93	27	67	354	381	47.62	-287
European Union	24.77	100	0	0	30	2.40	50	14	36	315	329	41.09	-278
India	0.00	0	15	5	30	3.22	126	0	126	0	0	0.00	126
World - Annex I	20.35	100	3	0	30	2.66	64	16	48	259	275	34.32	-210
World - High	3.15	100	6	0	30	2.21	57	13	44	40	53	6.63	4
World - Upper	7.82	75	10	0	30	15.54	465	70	395	99	169	21.17	296
World - Medium	1.11	35	15	10	30	8.56	364	18	346	14	32	4.01	332
World - Lower	0.00	0	20	10	30	9.01	408	0	408	0	0	0.00	408
Total	100.0C					56.11	1,877	207	1,670	1,270	1,476	184.54	400

(Note: 'World' totals do not include the individiual countries listed above.)

Table B2. Emissions to match Climate Action Tracker "Pledges and Targets Scenario"

Appendix B - NDC - China

https://climateactiontracker.org/countries/china/



https://www.vox.com/22313871/china-energy-climate-change-five-year-plan-wind-solar-coal-oil-gas) (Mar 5 2021)

In the long run, China has expressed a strong commitment to climate action. President Xi Jinping surprised the world last September when he announced that China would aim to reach carbon neutrality by 2060. Climate scientists have called for countries to hit that goal by 2050, but it was still a significant step forward for China — the first time the country made any formal commitment to zeroing out its emissions.

And yet, even as Xi made that announcement, CO2 emissions in China were soaring. Like the rest of the world, the pandemic had initially caused economic activity to plummet in China in early 2020. But after swiftly bringing the pandemic under control within its borders, the Chinese government funneled stimulus dollars into the heavily polluting construction and manufacturing sectors, stoking steel and cement production. As a result, China's emissions rose an estimated 1.5 percent in 2020, even accounting for the initial drop.

No silver bullet: China's carbon trading market

China's long-awaited carbon market started trading today. The emissions-trading system—which is the world's largest—was first announced in 2017, but missed its original launch date on June 30th.

Initially the market covers some 2,225 power plants that use fossil fuels, which produce between one-third and one-half of the country's entire emissions. But it will not do much to aid the Chinese government's goal of reaching net-zero emissions by 2060.

China has prioritised participation over the immediate reduction of emissions. Companies get large quotas to let them keep spewing out lots of carbon; fines for breaching the rules are low. Carbon prices started at less than 15% of Europe's. The Chinese government says that it intends to expand the market rapidly. For now, it will not change the country's status as the biggest polluter in the world.

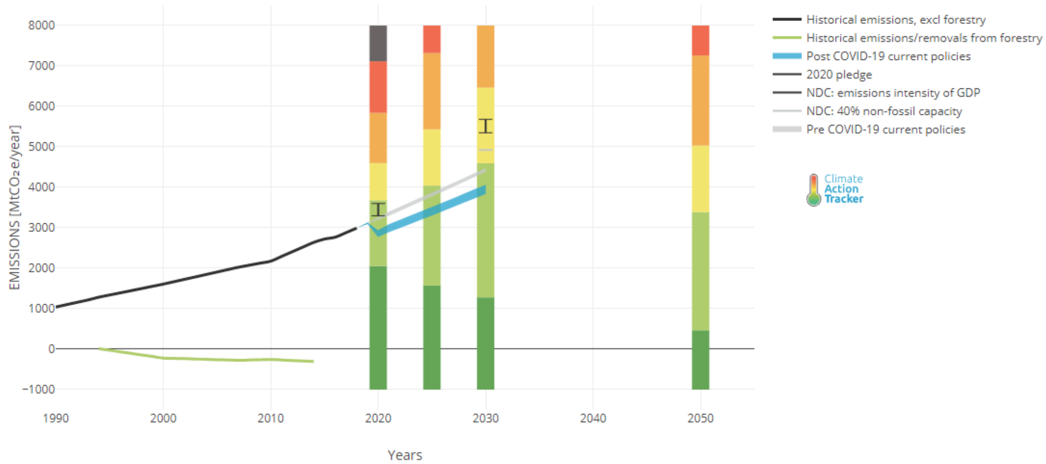
http://espresso.economist.com/b296faad3a199ff1e2c55075e1f544d2

Appendix C - NDC – India

https://climateactiontracker.org/countries/india/

Country summary

SUMMARY PLEDGES AND TARGETS FAIR SHARE CURRENT POLICY PROJECTIONS ASSUMPTIONS SOURCES



Graph Footnotes INSTRUCTIONS: Click each data series legend item above to deactivate or activate on the graph. To zoom in on the graph - click and drag to create a box - then release. To return to full scale, simply double click anywhere on the graph.

Climate change: Net zero targets are 'pie in the sky'
https://www.bbc.com/news/science-environment-56596200

A range of major carbon-producing countries, including the US, the UK, Japan and the EU, have signed up to the idea. Last September, China said it would get there by 2060.

India, the world's fourth largest emitter, doesn't seem keen to join the club.

"2060 sounds good, but it is just that, it sounds good," Raj Kumar Singh, India's minister for power, told a meeting organised by the International Energy Agency (IEA).

"I would call it, and I'm sorry to say this, but it is just a pie in the sky."

To the discomfort of his fellow panellists, Mr Singh singled out developed countries where per capita emissions are much higher than in India.

"You have countries whose per capita emissions are four or five or 12 times the world average. The question is when are they going to come down?"

"What we hear is that by 2050 or 2060 we will become carbon neutral, 2060 is far away and if the people emit at the rate they are emitting the world won't survive, so what are you going to do in the next five years that's what the world wants to know."

Mr Singh pointed out that while it was the richer countries who had burned most of the fossil fuels that have caused the problems, they now wanted developing countries to stop - that was unfair, he said.

"The developed world has occupied almost 80% of the carbon space already, you have 800 million people who don't have access to electricity. You can't say that they have to go to net zero, they have the right to develop, they want to build skyscrapers and have a higher standard of living, you can't stop it," he told the meeting.

Footnotes

1

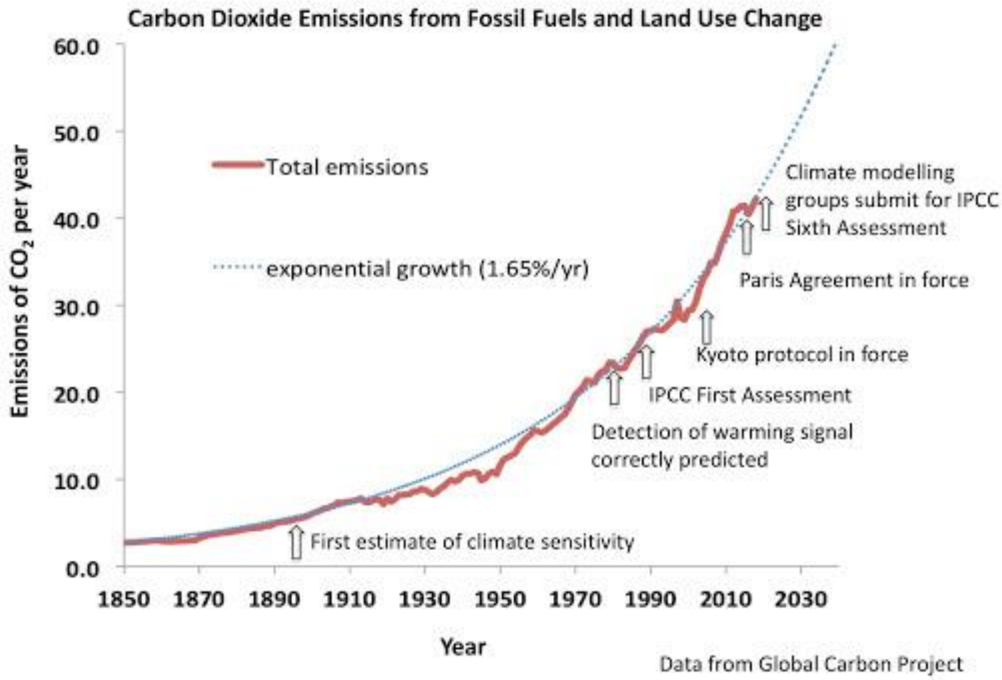
Table SPM.2: Estimates of historical CO_2 emissions and remaining carbon budgets. Estimated remaining carbon budgets are calculated from the beginning of 2020 and extend until global net zero CO_2 emissions are reached. They refer to CO_2 emissions, while accounting for the global warming effect of non-CO_2 emissions. Global warming in this table refers to human-induced global surface temperature increase, which excludes the impact of natural variability on global temperatures in individual years. {Table TS.3, Table 3.1, Table 5.1, Table 5.7, Table 5.8, 5.5.1, 5.5.2, Box 5.2}

Global warming between 1850–1900 and 2010–2019 *(°C)*	Historical cumulative CO_2 emissions from 1850 to 2019 *($GtCO_2$)*
1.07 (0.8–1.3; *likely* range)	2390 (± 240; *likely* range)

Approximate global warming relative to 1850–1900 until temperature limit *(°C)**(1)	Additional global warming relative to 2010–2019 until temperature limit *(°C)*	Estimated remaining carbon budgets from the beginning of 2020 *($GtCO_2$)* *Likelihood of limiting global warming to temperature limit*(2)*					Variations in reductions in non-CO_2 emissions*(3)
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

*(1) Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.
*(2) This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks, and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.
*(3) Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

2A



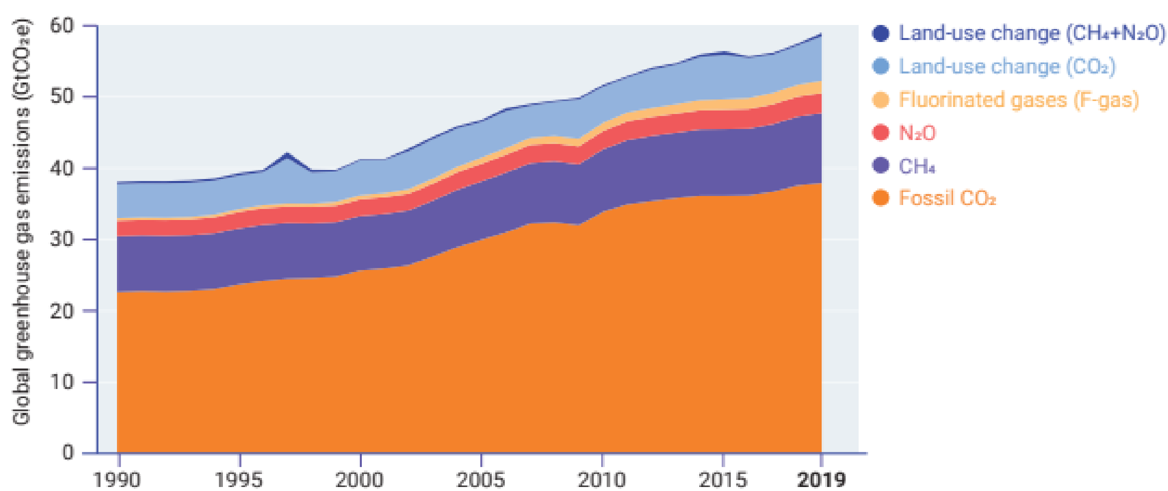
https://extinctionrebellion.uk/the-truth/the-emergency/part-1/

2B

Emissions Gap Report 2020

total GHG emissions, reached a new high of 59.1 Gt of CO_2 equivalent ($GtCO_2e$) when including land-use change (LUC), and 52.4 $GtCO_2e$ without LUC,

Figure ES.1. Global GHG emissions from all sources



Fossil Fuel Emissions: 36 GTCO2 (other sources)
Land Use Change Emissions 6 GTCO2
Total 42 GTCO2
https://www.unep.org/emissions-gap-report-2020

Fossil Fuel Emissions: 36.44 GTCO2 (other sources)
Land Use Change Emissions 6.6 GTCO2
Total 43.04 GTCO2
https://www.statista.com/statistics/276629/global-co2-emissions/

Table 2.1. Key statistics for GHG emissions shares and trends and highest emitting countries and regions

	GHG emissions 2019 ($GtCO_2e$)	GHG emissions 2019 (tCO_2e/person)	Emissions share 2010–2019 (%)	Emissions growth 2010–2019 (%/yr)	Growth in 2019 (%)
Fossil CO_2	38		65	1.3	0.9
Methane (CH_4)	9.8		17	1.2	1.3
Nitrous oxide (N_2O)	2.8		4.9	1.1	0.8
Fluorinated gases	1.7		2.6	4.7	3.8
GHGs without LUC	**52.4** (range: ±5.2)		**89**	**1.4**	**1.1**
LUC CO_2	6.3		10	1.3	13.3
LUC CH_4 & N_2O	0.5		0.5	3.7	84.6
GHGs with LUC	**59.1** (range: ±5.9)		**100**	**1.4**	**2.6**
Countries (GHGs without LUC)					
China	14	9.7	26	2.3	3.1
United States of America	6.6	20.0	13	-0.1	-1.7
EU27+UK	4.3	8.6	9.3	-1.1	-3.1
India	3.7	2.7	6.6	3.3	1.3
Russian Federation	2.5	17.4	4.8	1	0.8
Japan	1.4	10.7	2.8	0.1	-1.6
International transport	1.4		2.5	2.3	2.9
GHGs without LUC	**52.4** (range: ±5.2)	**6.8**	65	**1.4**	**1.1**

Fossil Fuel Emissions - Energy related	33.30
Fossil Fuel Emissions - Other	3.14
Fossil Fuel Emissions -Total	36.44
Other	1.56
Total	38.00
Land Use Change Emissions (>0)	12.62
Land Use Change Emissions (<0)	-7.24
Other	0.92
Total CO2	6.30
LUC CH4 and N20	0.50
Total	6.70
TotalCO2	44.70
Total CO2 Emissions	

Methane (CH4)	9.80
Nitrous oxide (N2O)	2.80
Fluorinated gases	1.70
Other Non-GHG	0.10
Non CO2 GHG	14.40
Total	59.10

https://www.unep.org/emissions-gap-report-2020

3 US Emissions (GTCO2)

5.29	CO2
1.39	Other
6.68	Total GHG
-0.77	Land use changes
4.52	Net CO2
40	CO2 removal for net-zero pathway (=annual GHG emissions * 6 = 6.68 * 6)
140	US Gross emissions in a "net zero in 2050 pathway (=annual emissions * 21 = 6.68* 21)
100	Net CO2 Emissions (=annual emissions * 15 = 6.68 *15)
-46.2	Land Use changes 2021-2080 (=-0.77*60)
	US CDR requirement for US net zero is met by US LUCF

5 Causes of Deforestation - One Tree Planted
https://onetreeplanted.org/blogs/stories/deforestation-causes

What Is Deforestation? Definition, Causes, Effects and Solutions to Stop it
https://youmatter.world/en/definition/definitions-what-is-definition-deforestation-causes-effects/

Global Deforestation Rates & Statistics by Country | GFW
https://www.globalforestwatch.org/global/

Why is it so incredibly hard to stop deforestation?
https://forestsnews.cifor.org/30813/why-is-it-so-incredibly-hard-to-stop-deforestation?

We found that despite diverse legal systems and varying levels of decentralization, powerful actors with a stake in deforestation often figure out how to get their way – whether using the rules to their advantage, or going around them.

www.epa.gov › ghgemissions › global-greenhouse-gas
Jul 27, 2021 · However, changes in land use can be important: estimates indicate that net global greenhouse gas emissions from agriculture, forestry, and other land use were over 8 billion metric tons of CO 2 equivalent, [2] or about 24% of total global greenhouse gas emissions. [3] In areas such as the United States and Europe, changes in land use associated with human activities have the net effect of absorbing CO 2, partially offsetting the emissions from deforestation in other regions.

Agriculture, Forestry, and Other Land Use (24% of 2010 global greenhouse gas emissions): Greenhouse gas emissions from this sector come mostly from agriculture (cultivation of crops and livestock) and deforestation. This estimate does not include the CO_2 that ecosystems remove from the atmosphere by sequestering carbon in biomass, dead organic matter, and soils, which offset approximately 20% of emissions from this sector.[2]

Tropical deforestation contributes about 20% of annual global greenhouse gas (GHG) emissions https://www.edf.org/sites/default/files/10333_Measuring_Carbon_Emissions_from_Tropical_Deforestation--An_Overview.pdf

New research, published in Nature Climate Change and available on Global Forest Watch, found that the world's forests sequestered about twice as much carbon dioxide as they emitted between 2001 and 2019. In other words, forests provide a "carbon sink" that absorbs a net 7.6 billion metric tonnes of CO2 per year,

https://www.wri.org/insights/forests-absorb-twice-much-carbon-they-emit-each-year

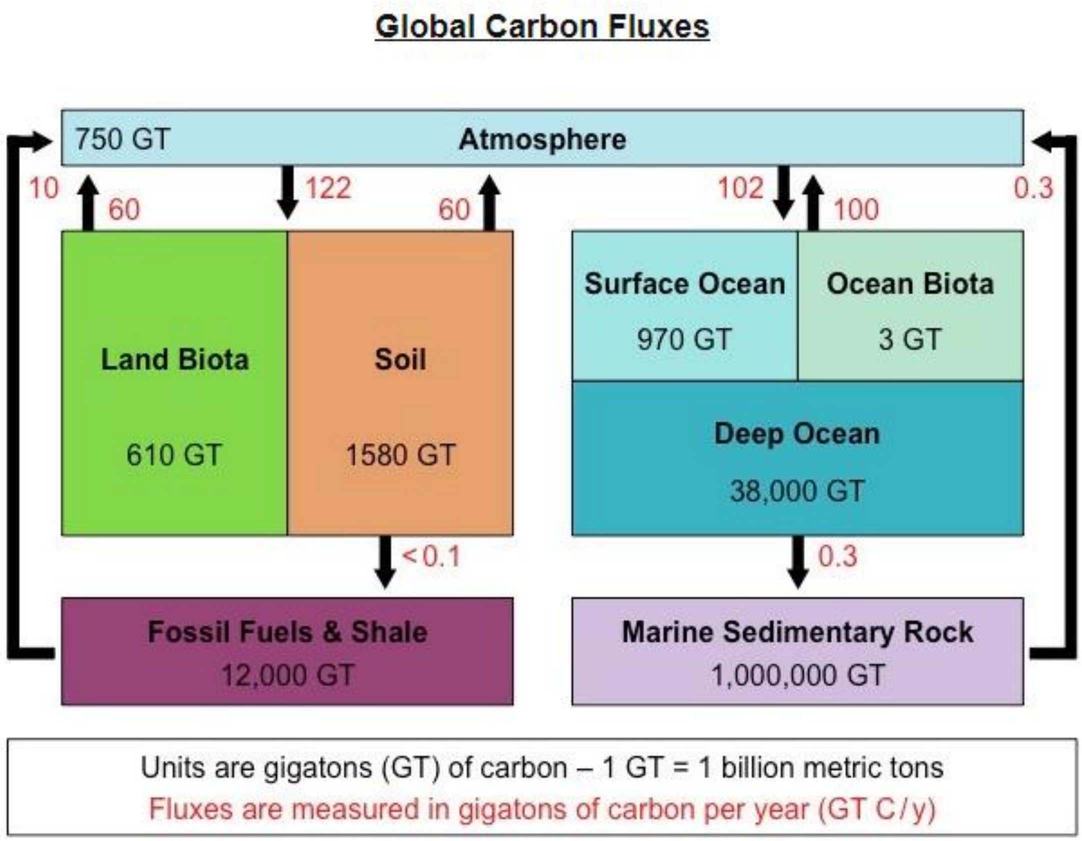
We estimate that global forests were a net carbon sink of −7.6 ± 49 $GtCO_2e\ yr^{-1}$, reflecting a balance between gross carbon removals (−15.6 ± 49 $GtCO_2e\ yr^{-1}$) and gross emissions from deforestation and other disturbances (8.1 ± 2.5 $GtCO_2e\ yr^{-1}$).

https://www.nature.com/articles/s41558-020-00976-6

The global ocean absorbed 34 billion metric tons of carbon from the burning of fossil fuels from 1994 to 2007 — a four-fold increase to 2.6 billion metric tons [9.5 GTCO2] per year when compared to the period starting from the Industrial Revolution in 1800 to 1994.

https://www.noaa.gov/news/global-ocean-is-absorbing-more-carbon-from-fossil-fuel-emissions

Atmosphere (45%)	16.2
Land (remainder)	10.3
Oceans	9.5
Total	36



https://ib.bioninja.com.au/standard-level/topic-4-ecology/43-carbon-cycling/carbon-fluxes.html