Getting to Net-Zero and Beyond:

What are the stakes? && What will it take?

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Earth Talks, Penn State University

14 Mar 2022

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U.S. DEPARTMENT OF ENERGY

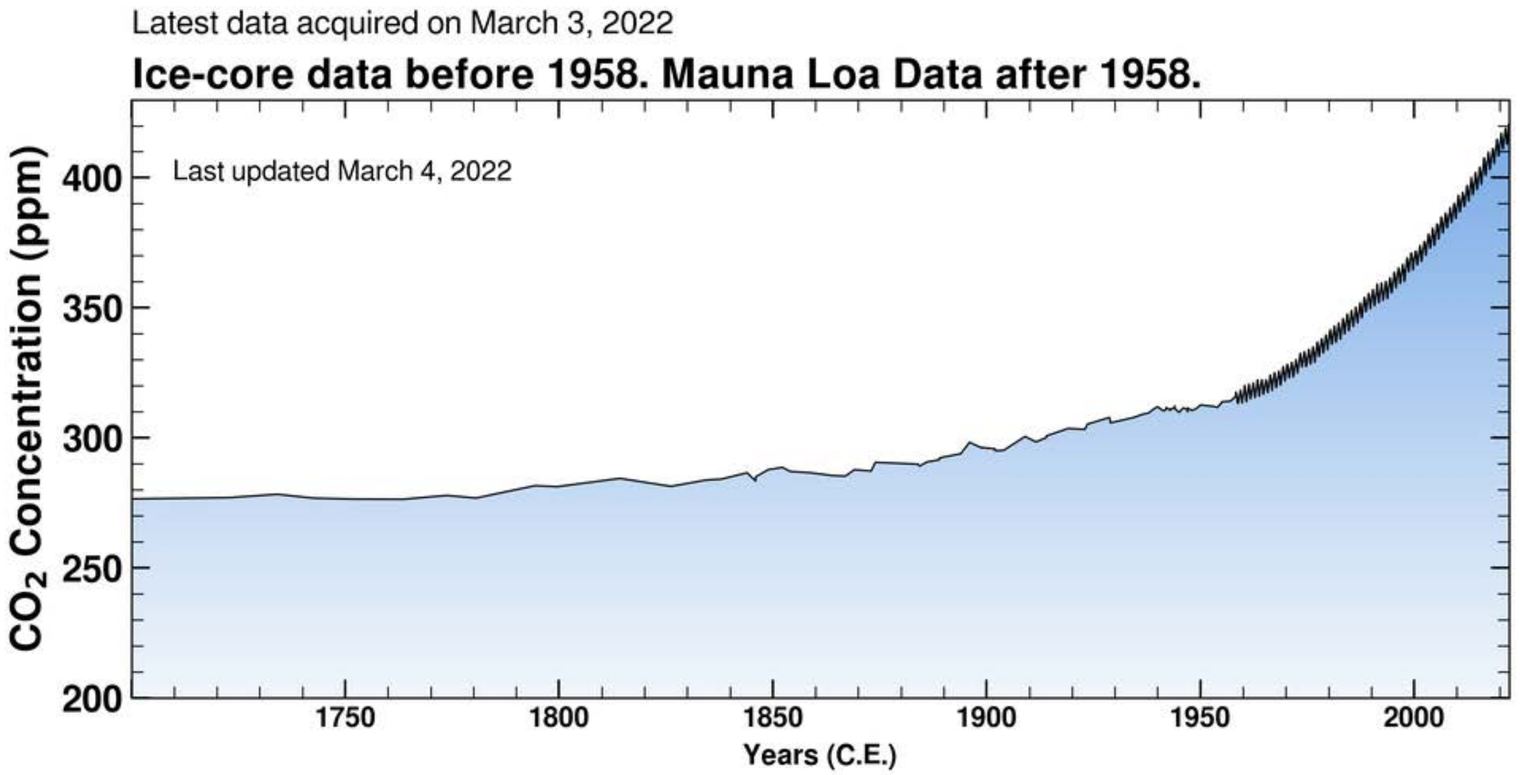
Office of Science

Getting to Net-Zero and Beyond

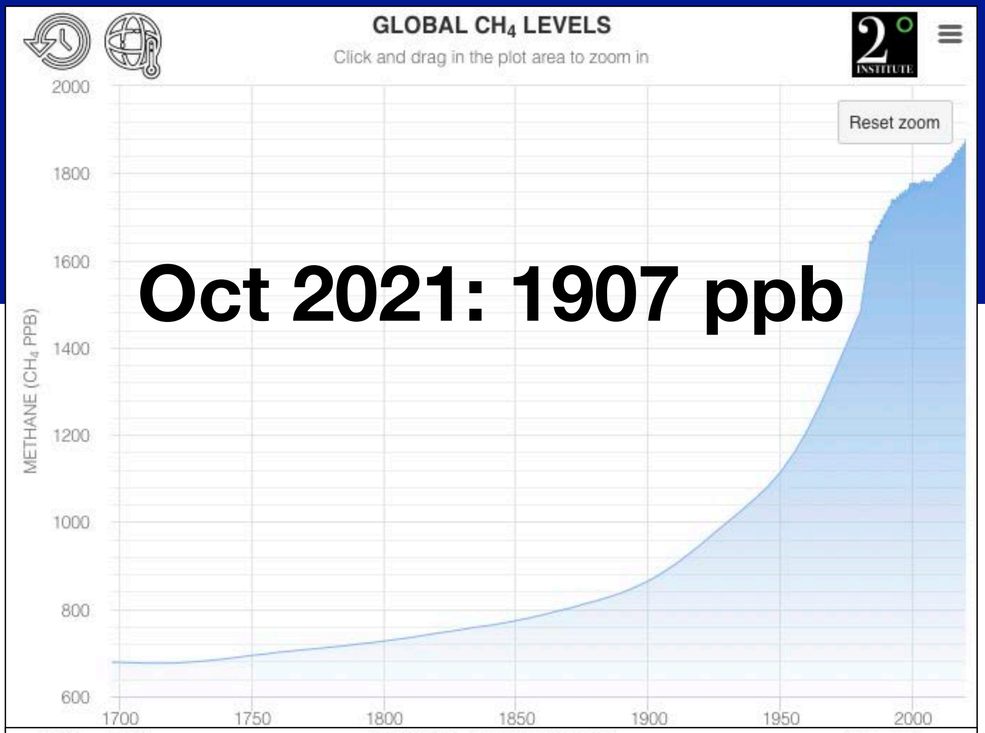
- Part 1: What are the stakes?
  - 1.1 Where are we now?
  - 1.2 What does NetZero really mean?
  - 1.3 Where are the planetary boundaries for Earth?
- Part 2: What will it take?
  - 2.1 Can we reduce emissions to Zero by 2050?
  - 2.2 Can we go beyond net-zero with net carbon storage?
- Part 3: What future do we choose? What stands in the way?

Global current concentrations of Greenhouse Gases

Highest Global [CO2]: 421ppm (Feb 14, 2022)



Sources: https://scripps.ucsd.edu/programs/keelingcurve/



Oct 2021: 1907 ppb

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https://www.2degreesinstitute.org

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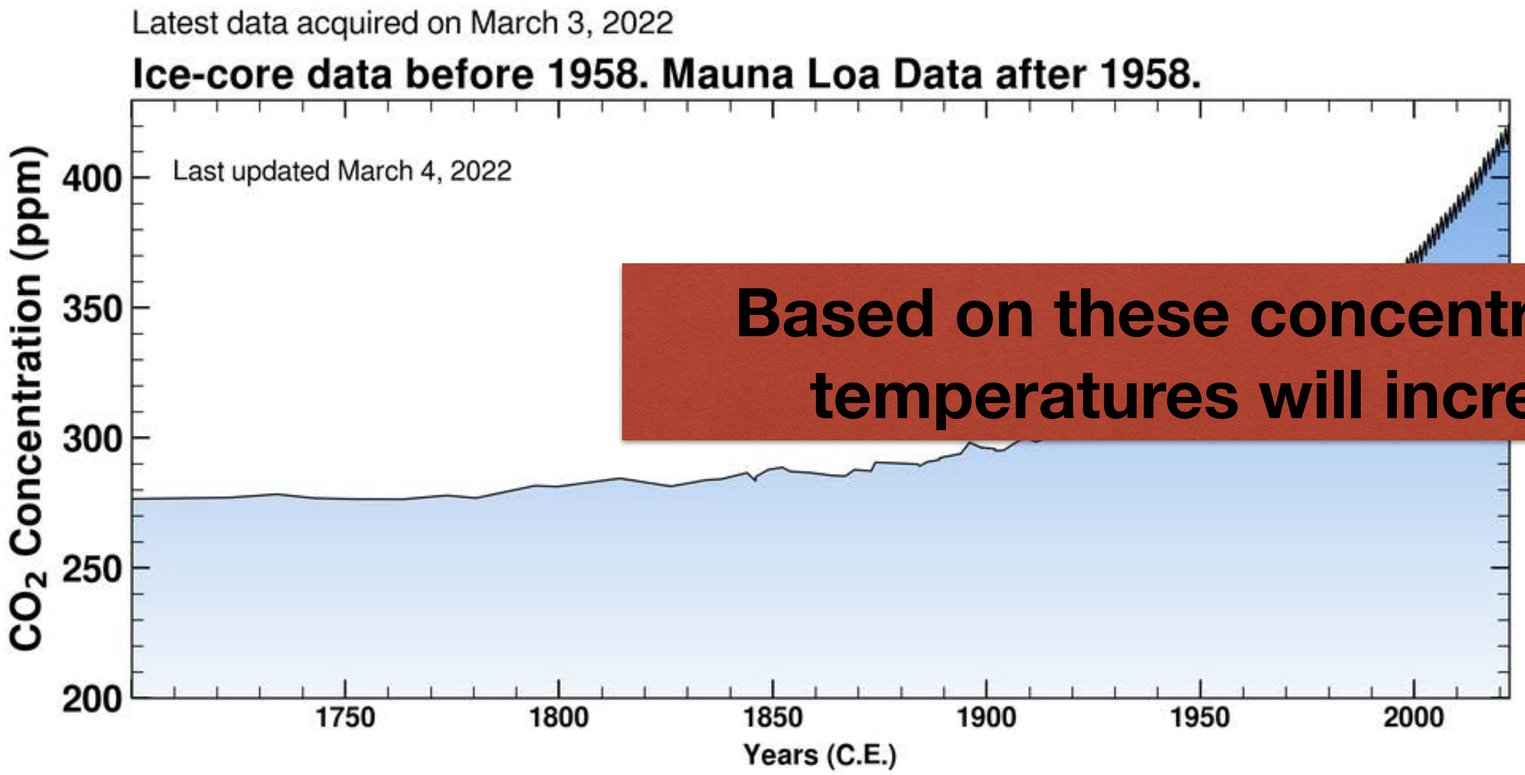
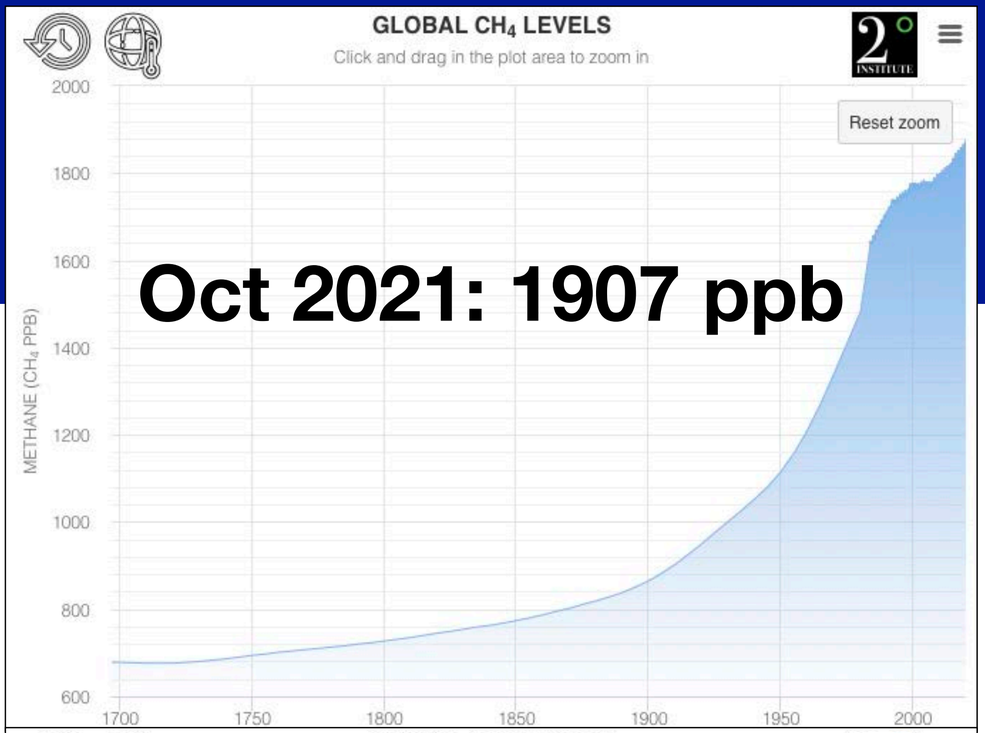


Based on these concentrations, temperatures will increase.



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1.1 Where are we now?

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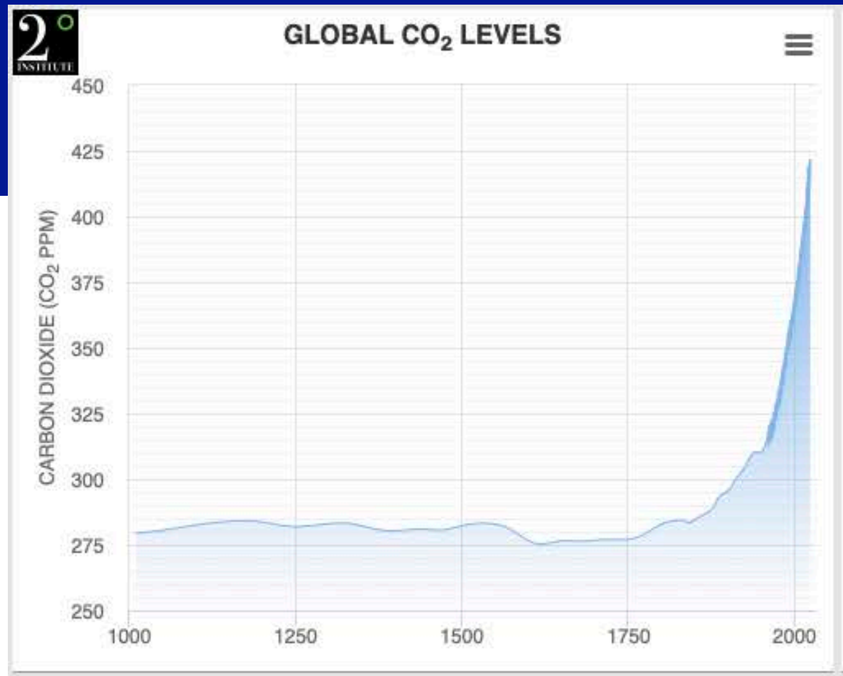

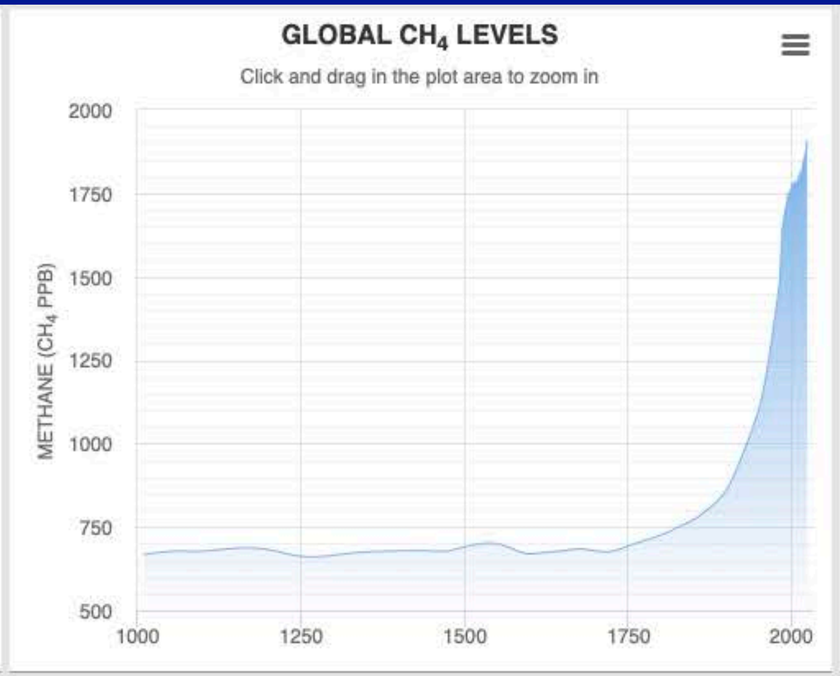

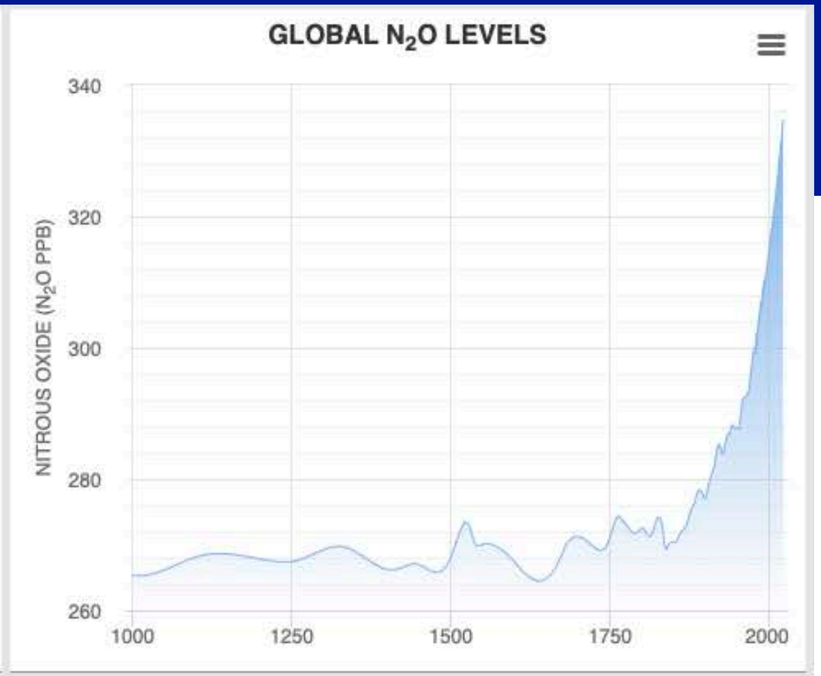

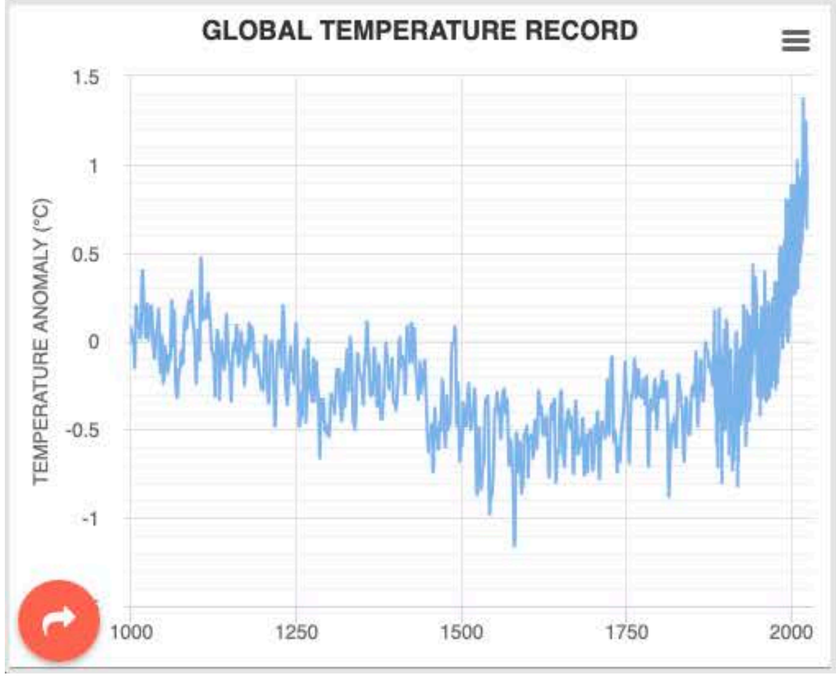

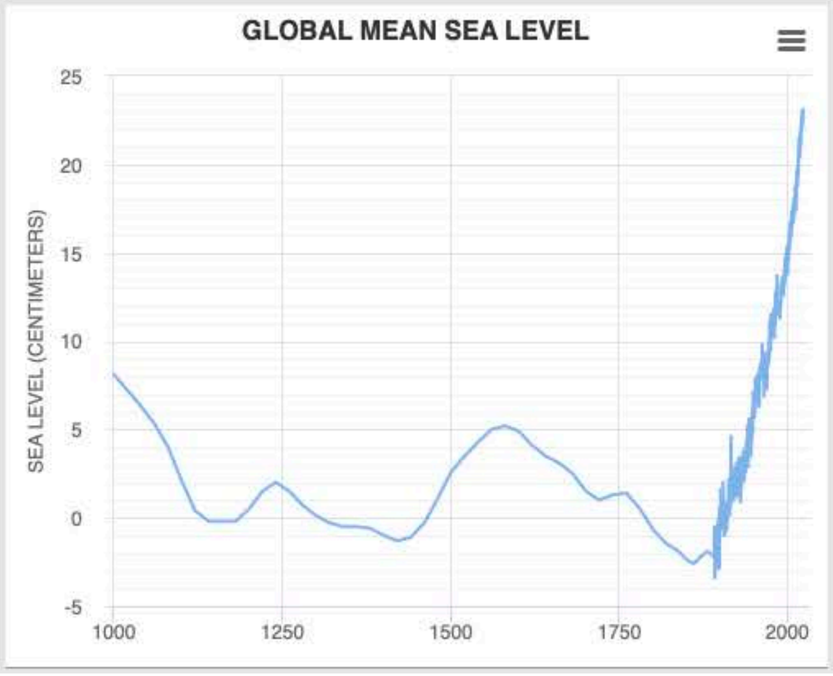

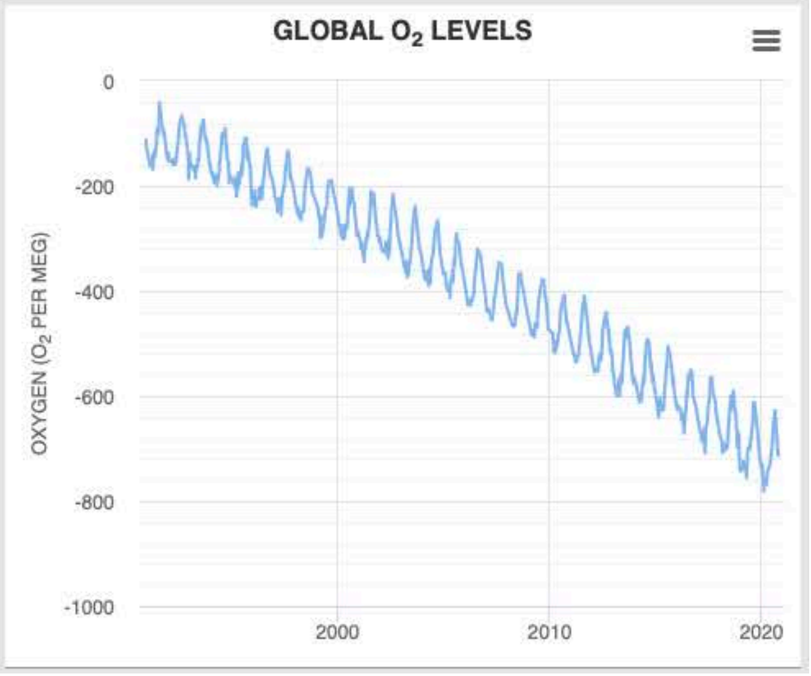

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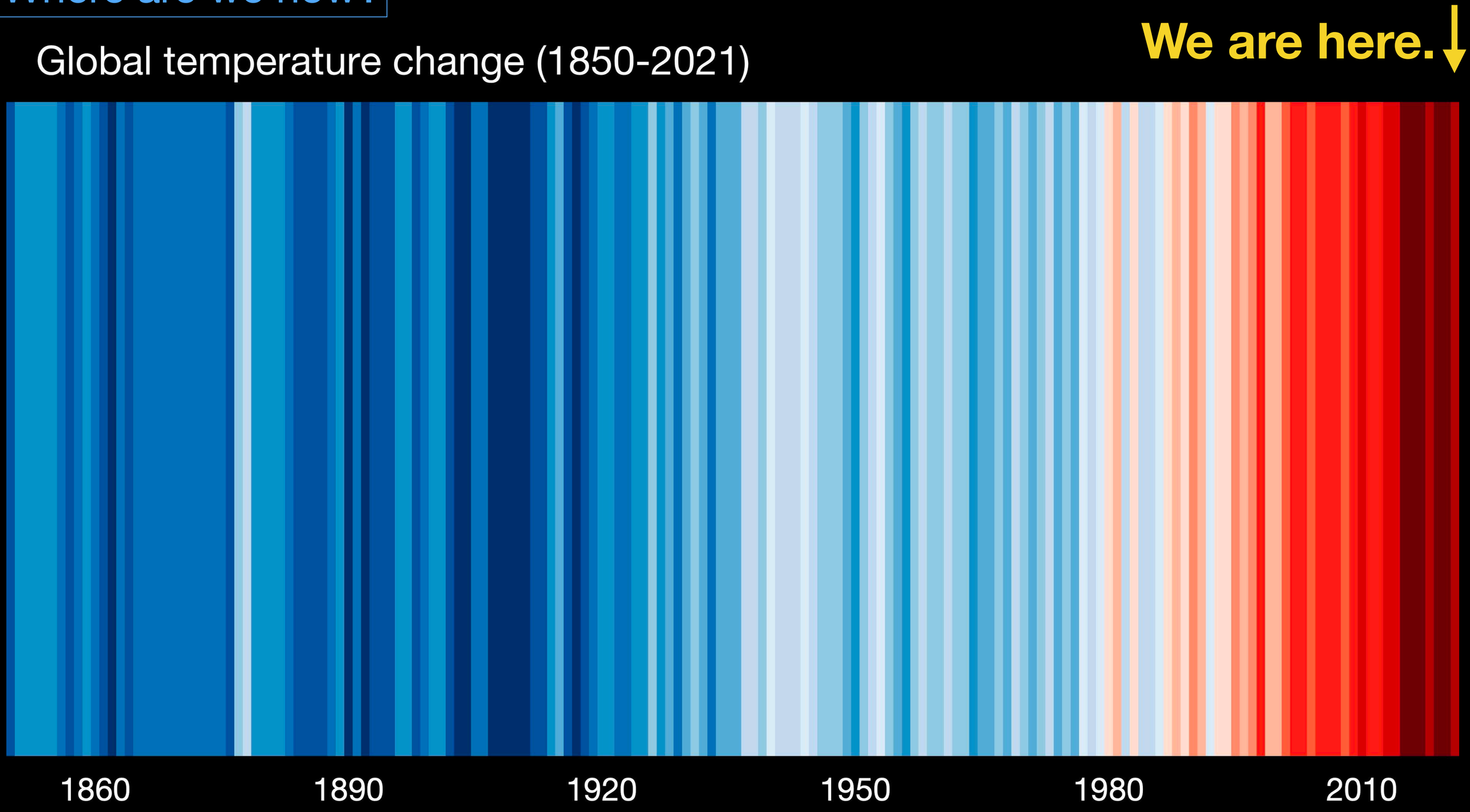
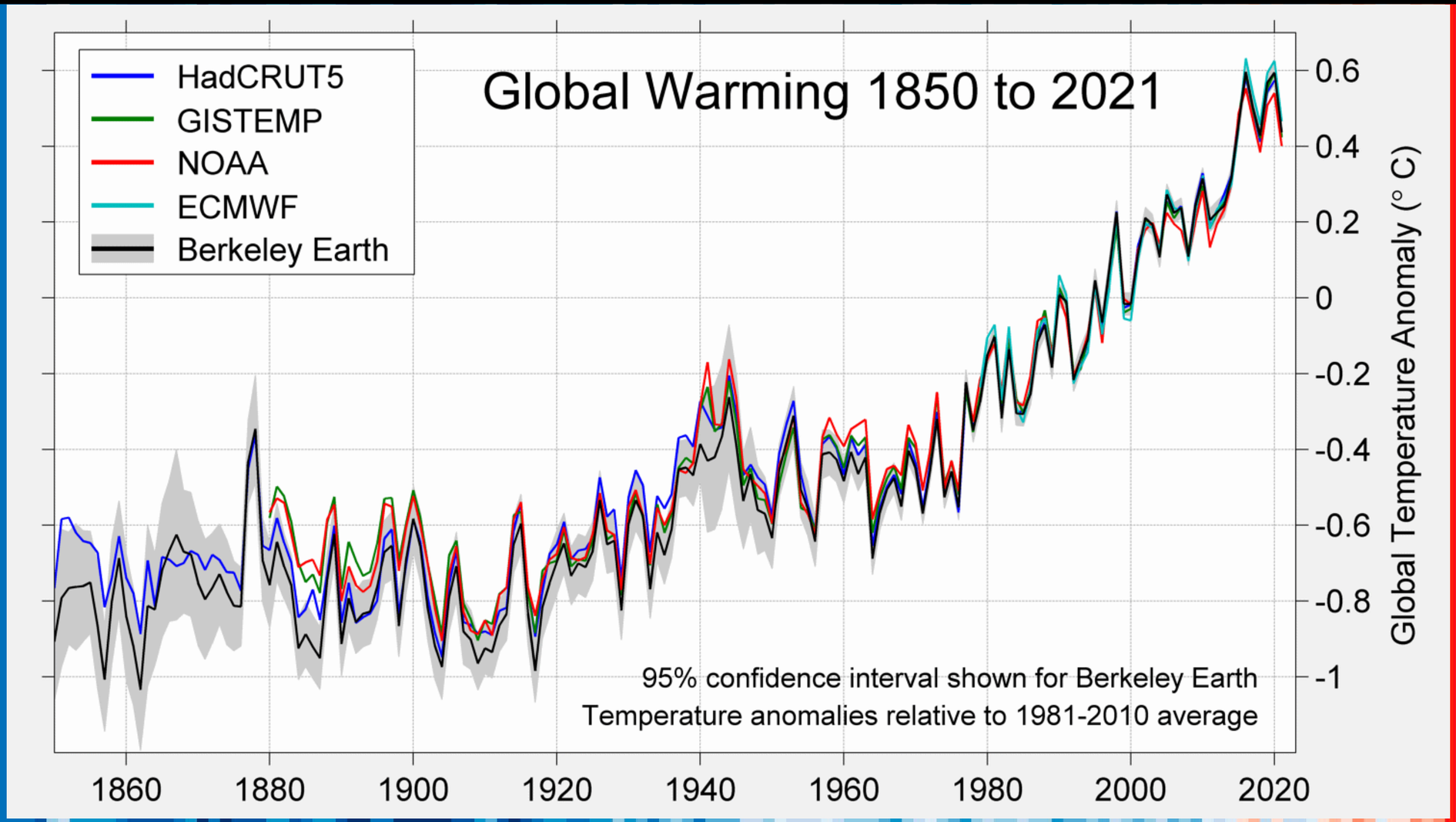


why NetZero?

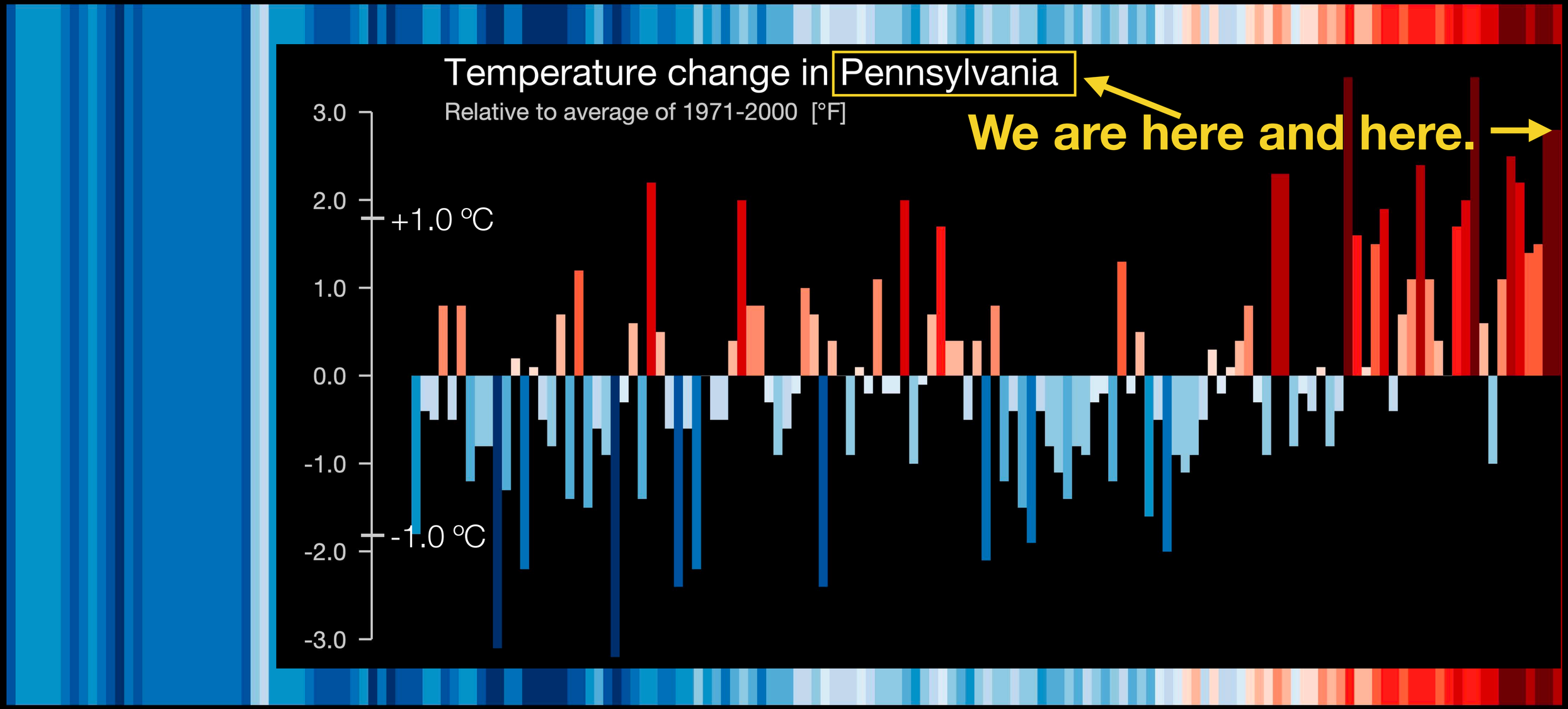
We are here.



http://berkeleyearth.org/global-temperature-report-for-2021/

1.1 Where are we now?

Global temperature change (1850-2021)



https://showyourstripes.info/s/northamerica/usa/pennsylvania

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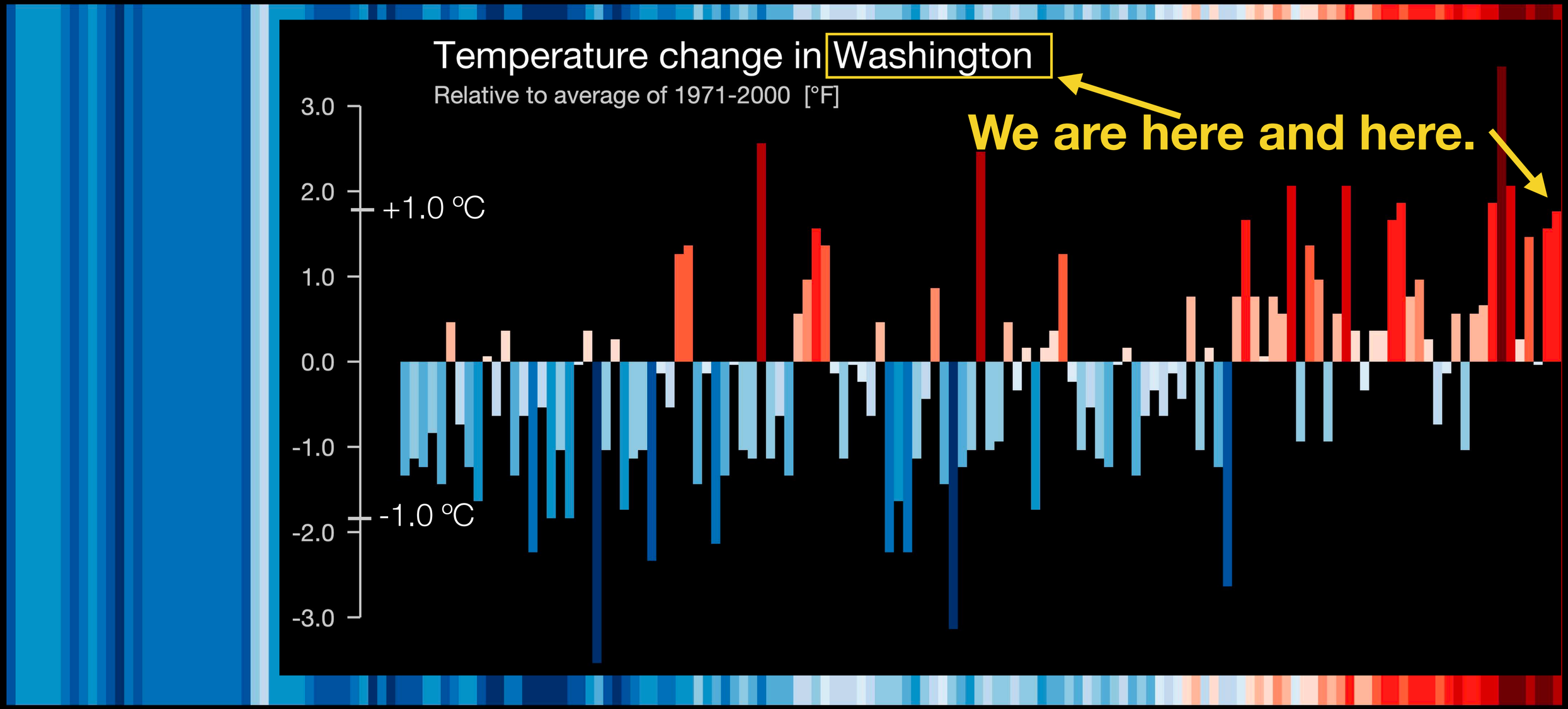

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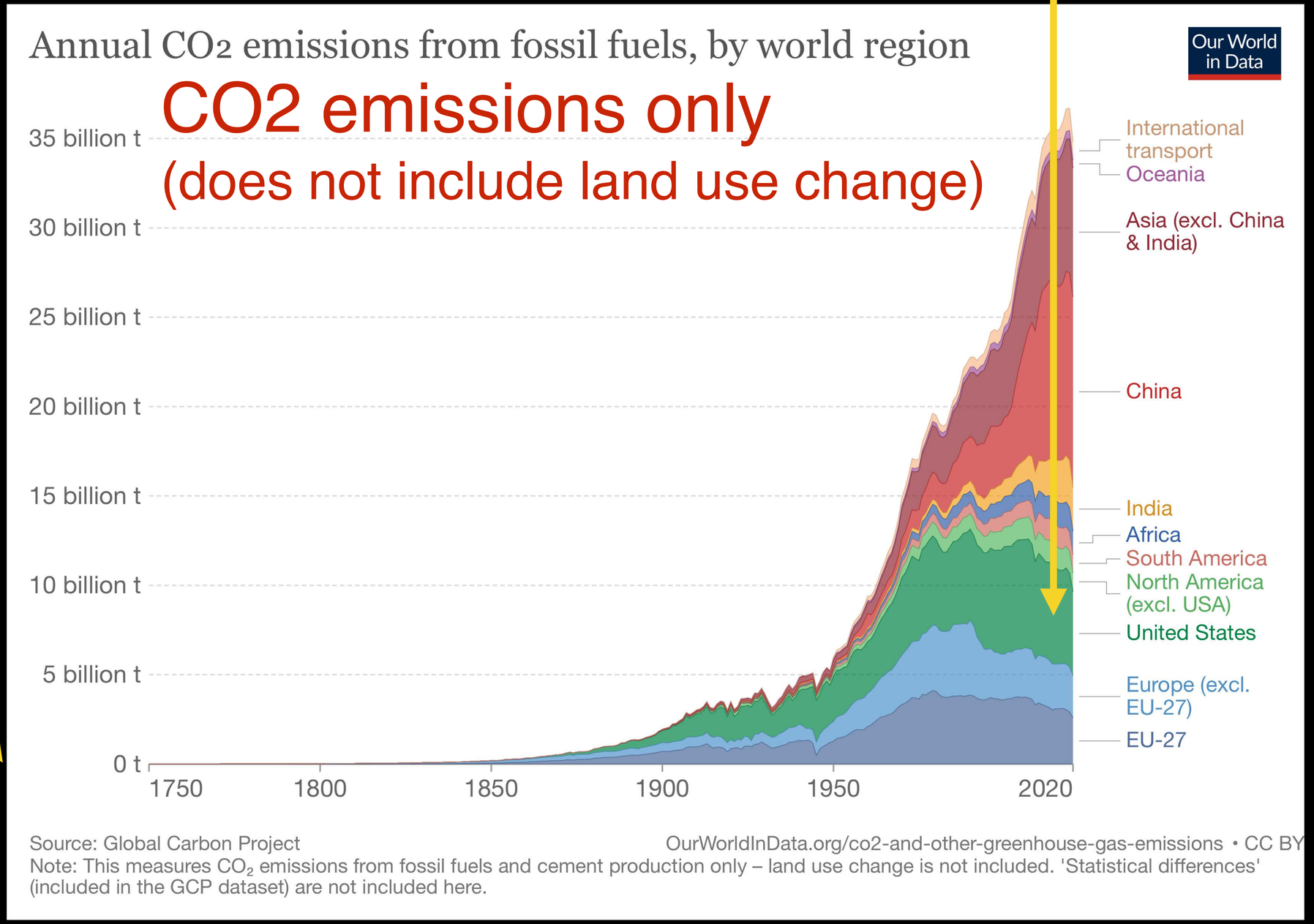
1.1 Where are we now?

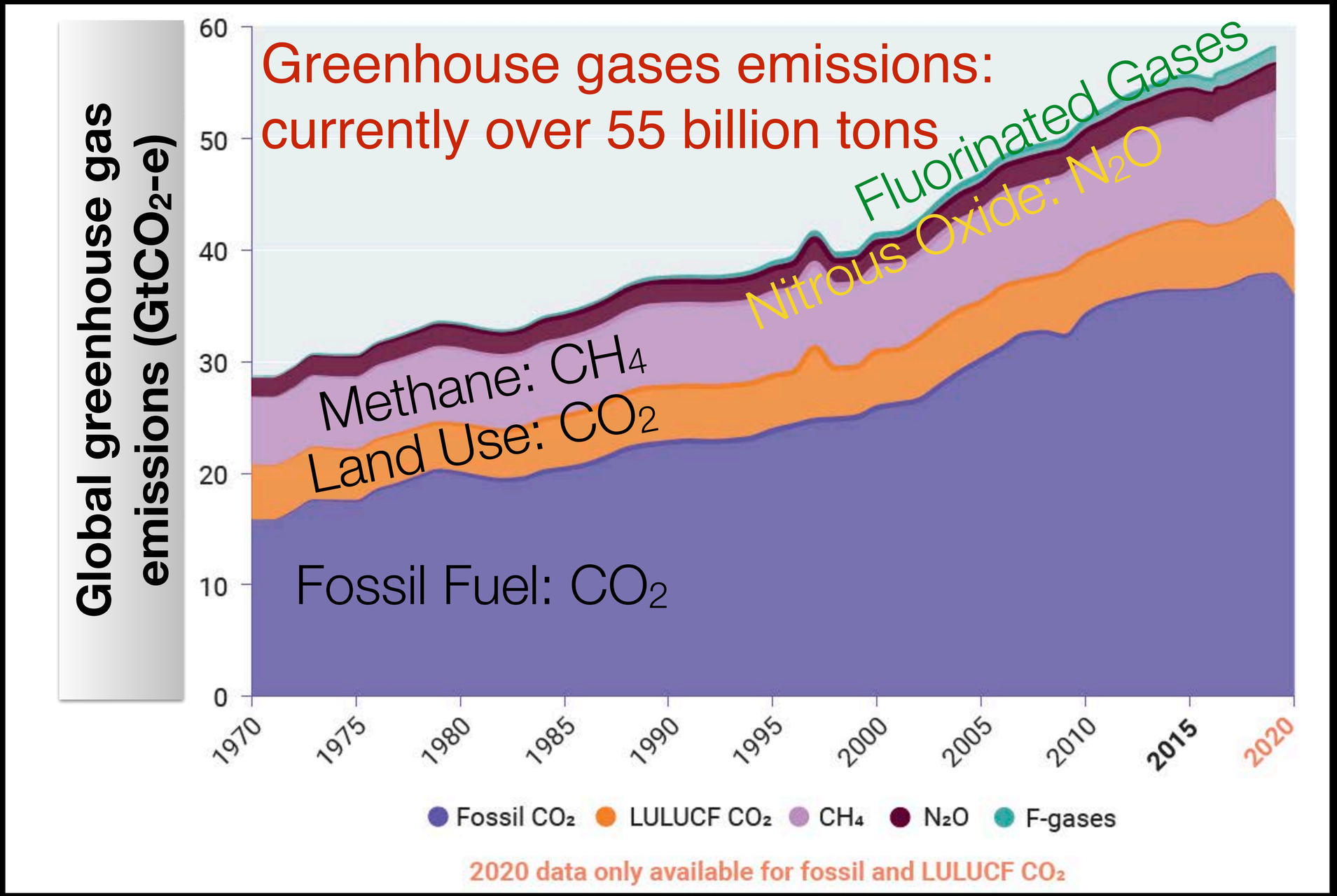
1698: Thomas Savery invented the steam engine pump water from coal mines and to burn more coal.

1712: Thomas Newcomen invented to piston driven pump.

1763-75: James Watt and Matthew Boulton improved the designs

We are here.





We are here.

UNEP (2021). Emissions Gap Report 2021: The Heat Is On – A World of Climate Promises Not Yet Delivered. Nairobi

1.2 What does NetZero really mean?

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Cumulative emissions of CO_2

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Cumulative emissions of CO_2
and future non-CO_2 radiative forcing
determine the probability
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(IPCC Special Report Global Warming of 1.5ºC, 2018)

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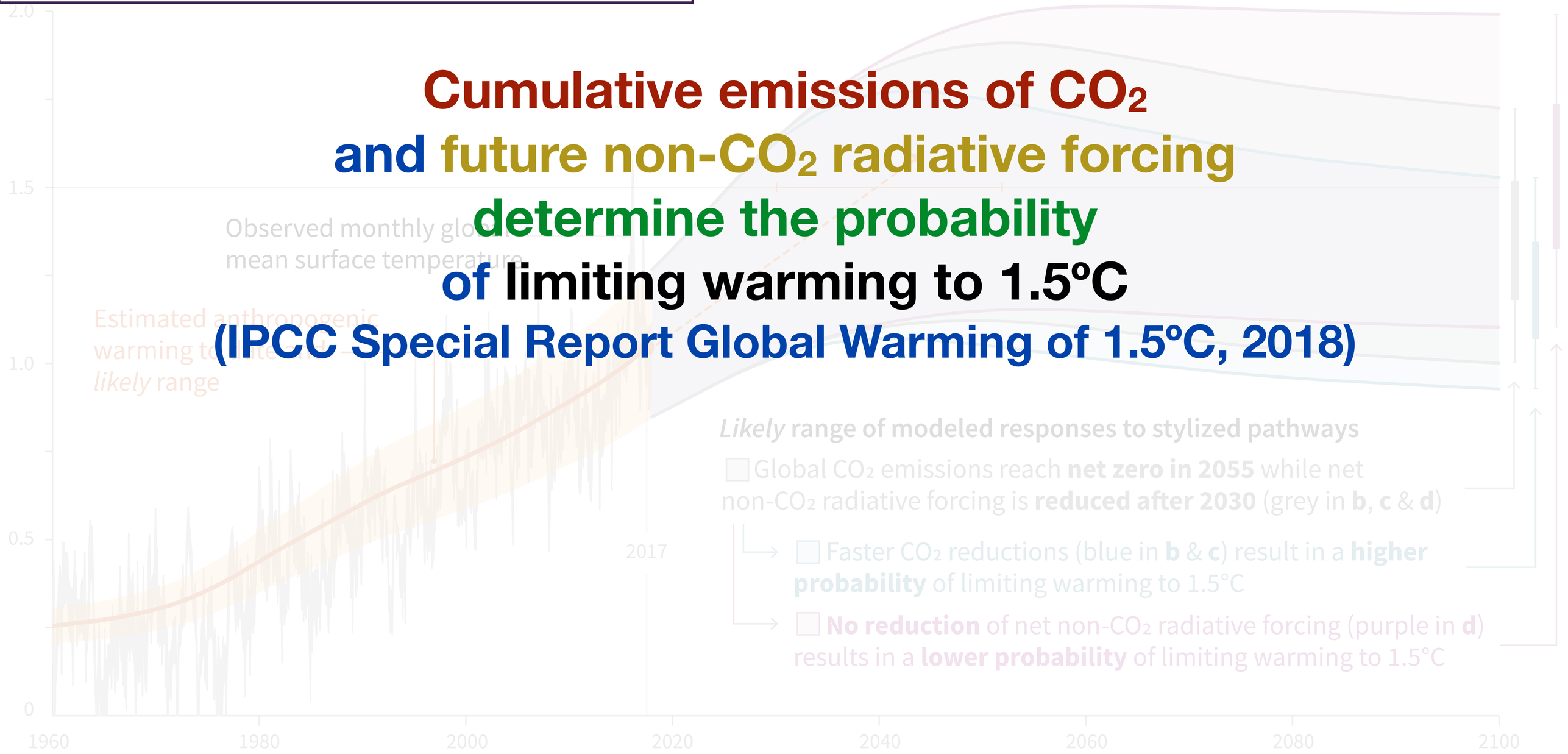

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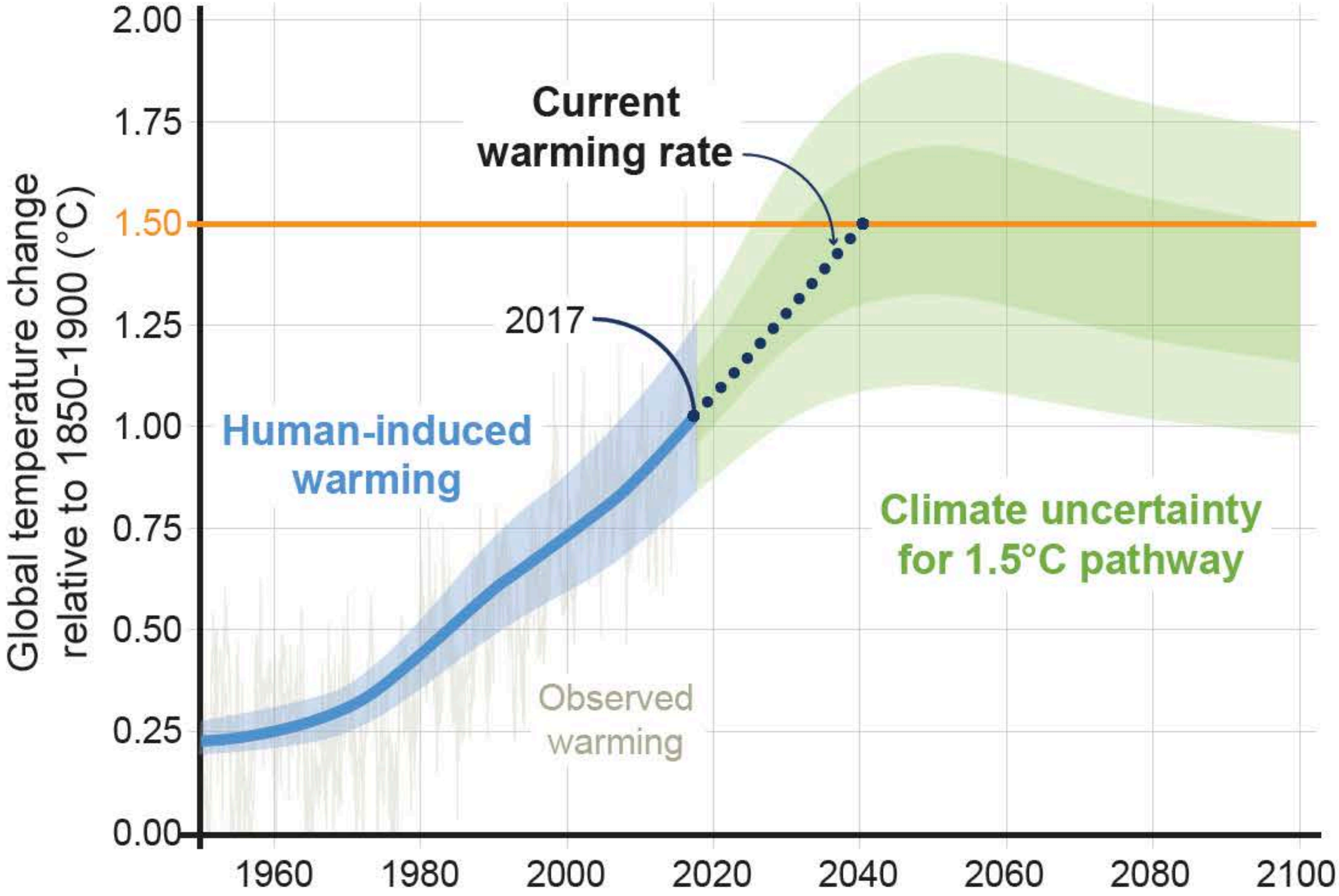

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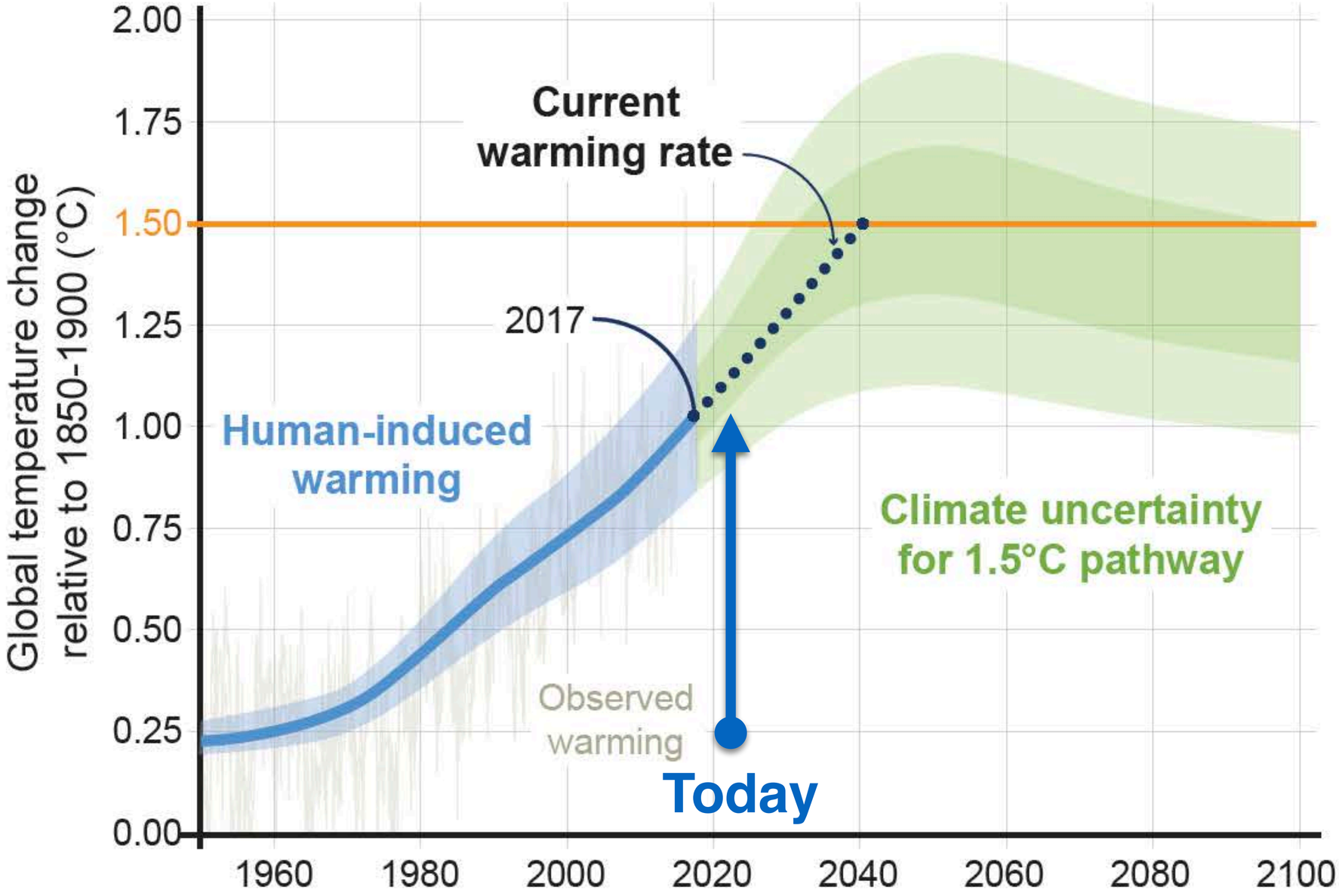

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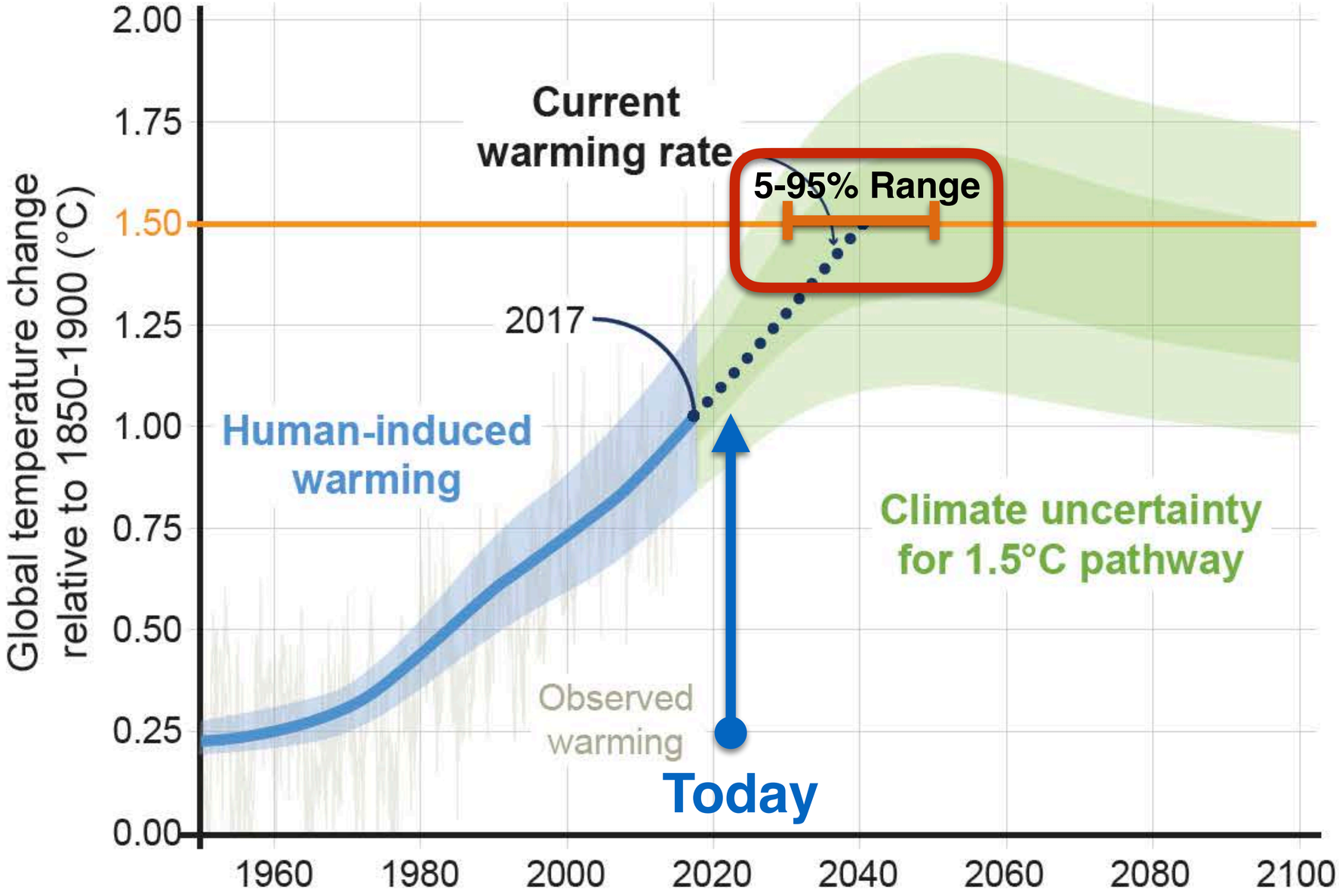

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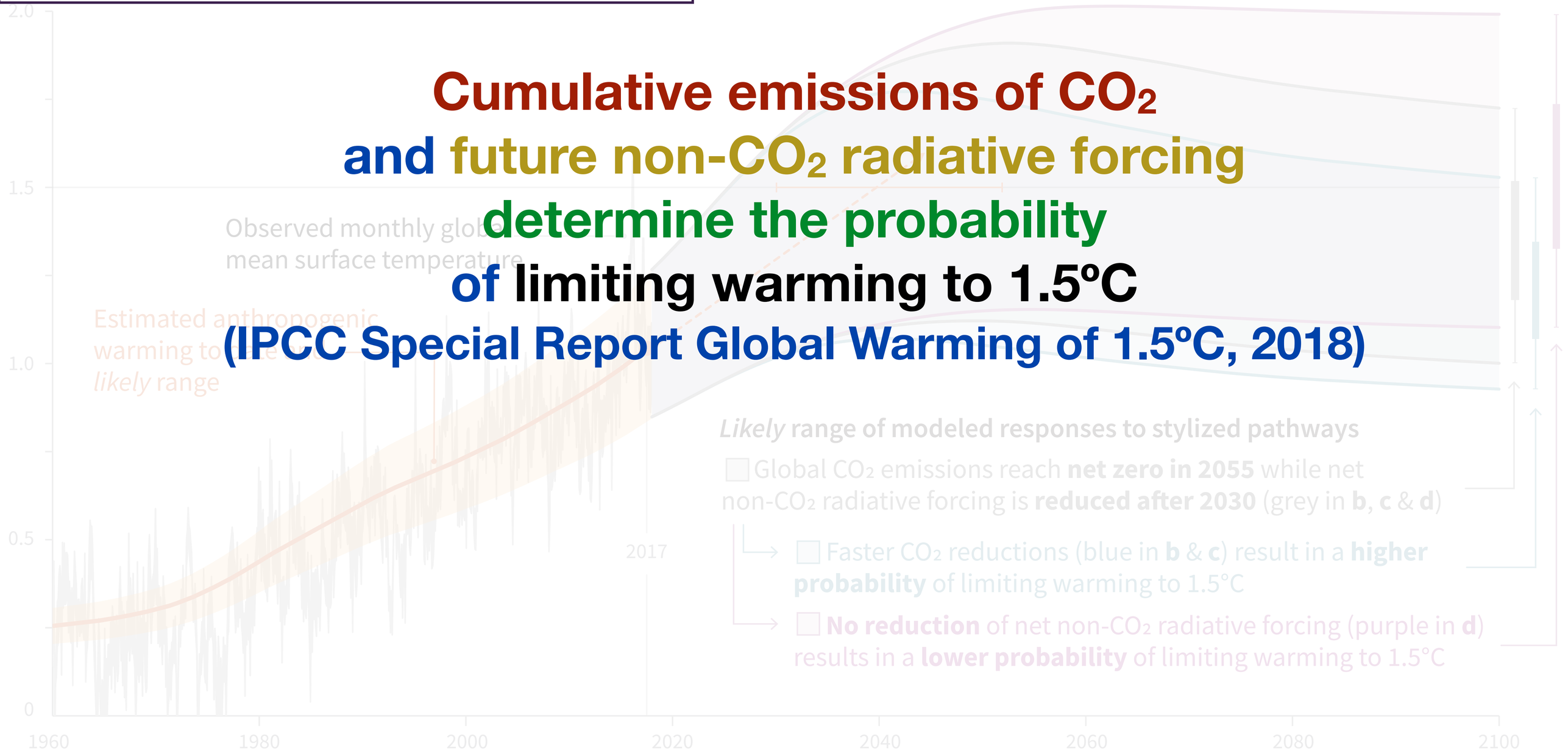

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Cumulative emissions of CO_2
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determine the net warming
(IPCC AR6 Working Group 1: SPM)

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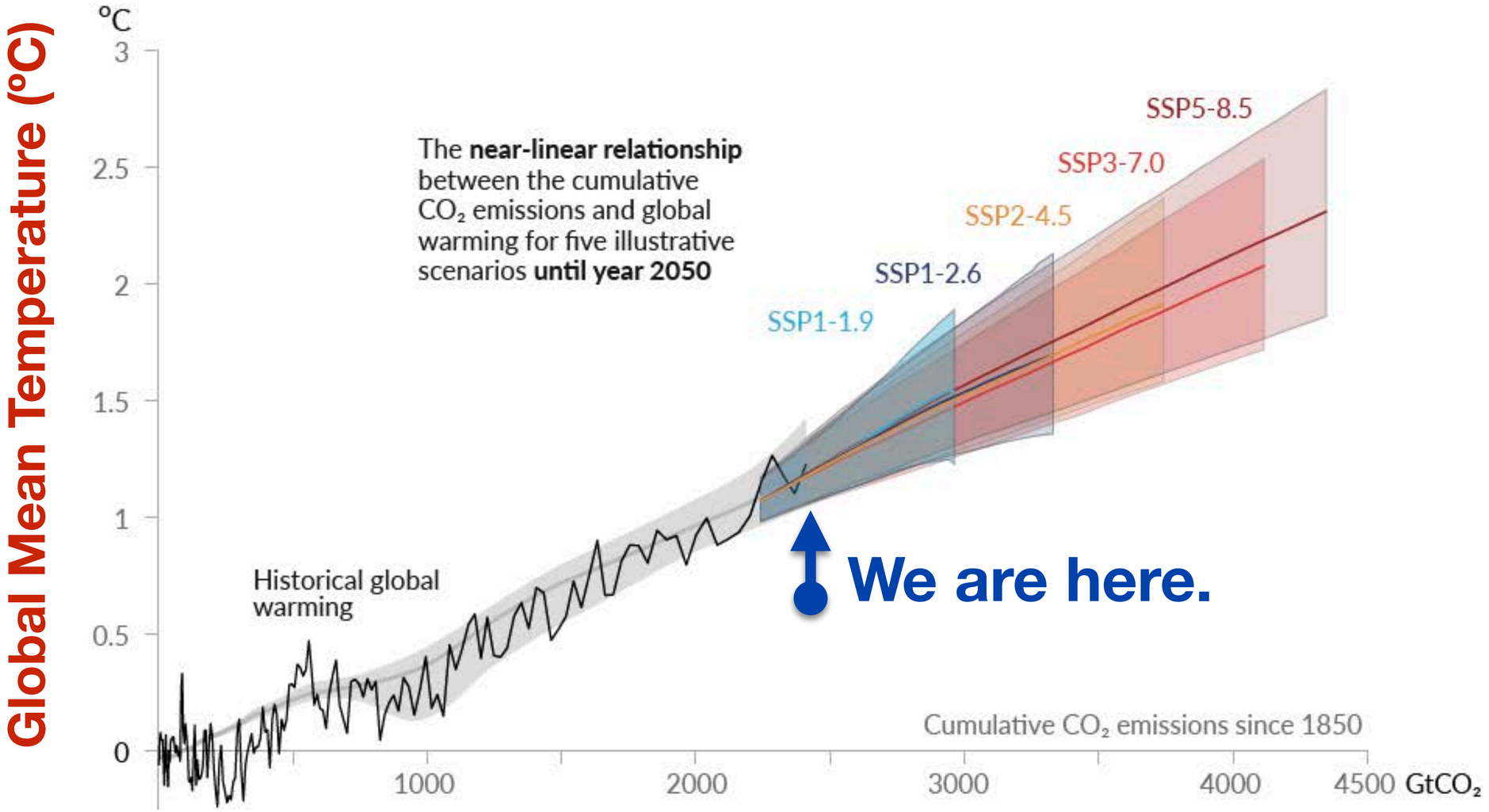
1.2 What does NetZero really mean?

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Cumulative CO_2 Emissions since 1850

IPCC AR6 WG1 SPM (August 2021)

https://www.ipcc.ch/report/ar6/wg1/

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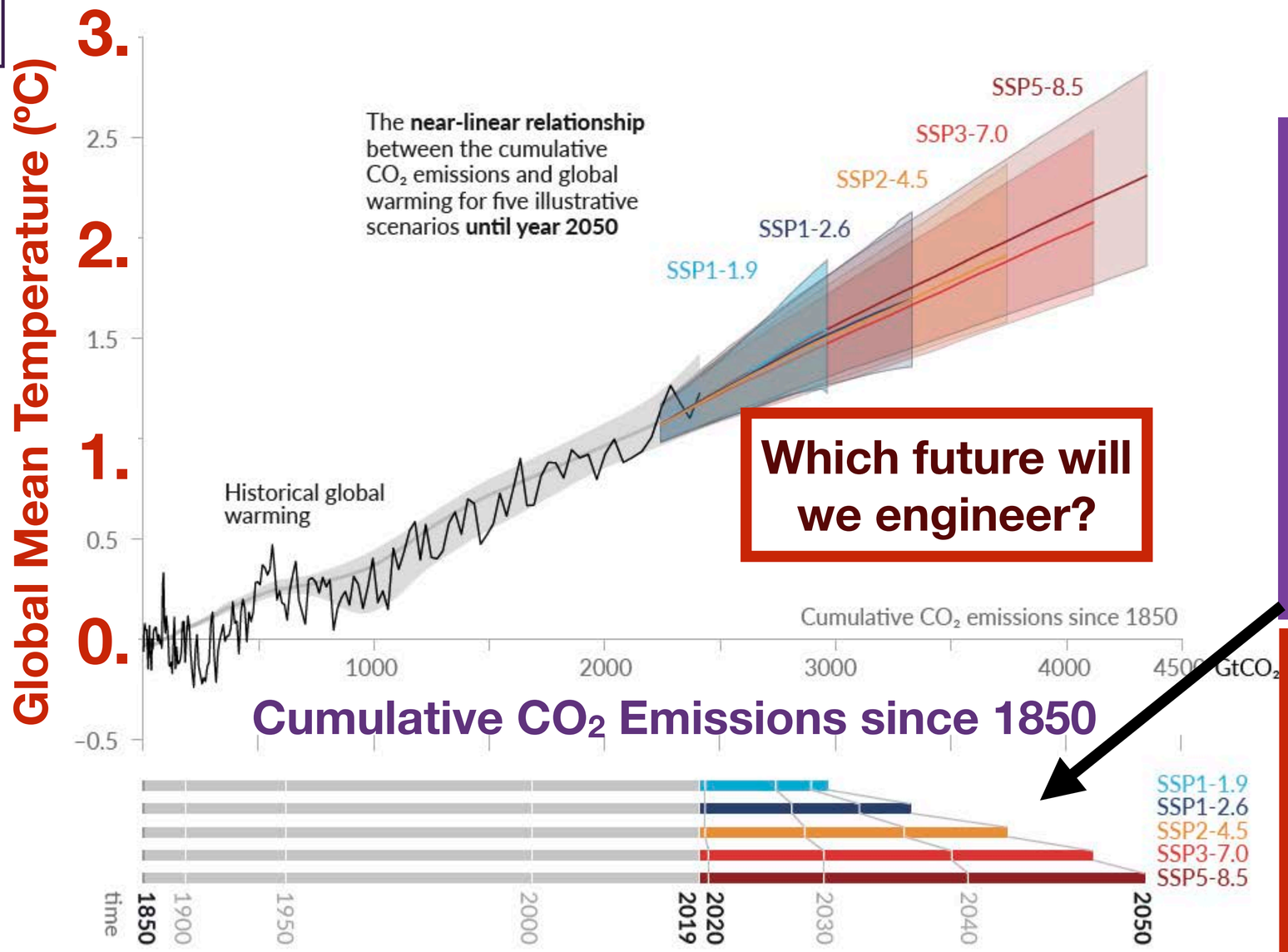


Which future will we engineer?

Future cumulative emissions determine how much warming we will experience.

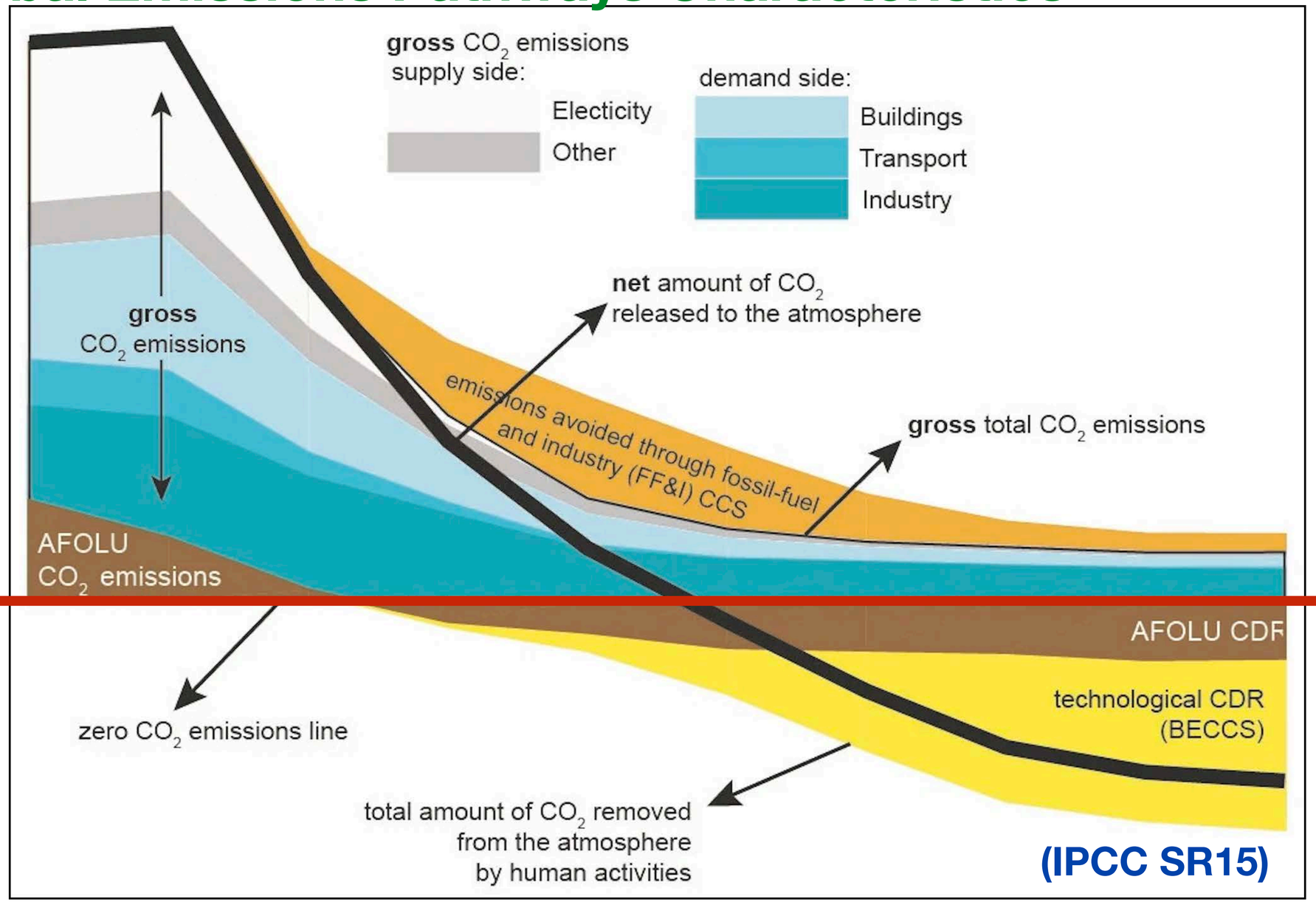
When we stop emitting, CO_2 concentrations and the climate will (eventually) stabilize.

[IPCC AR6 WG1 SPM (2021)]

https://www.ipcc.ch/report/ar6/wg1/#SPM

What pathways are consistent with NetZero?

Global Emissions Pathways Characteristics



Drawdown happens here

(IPCC SR15)

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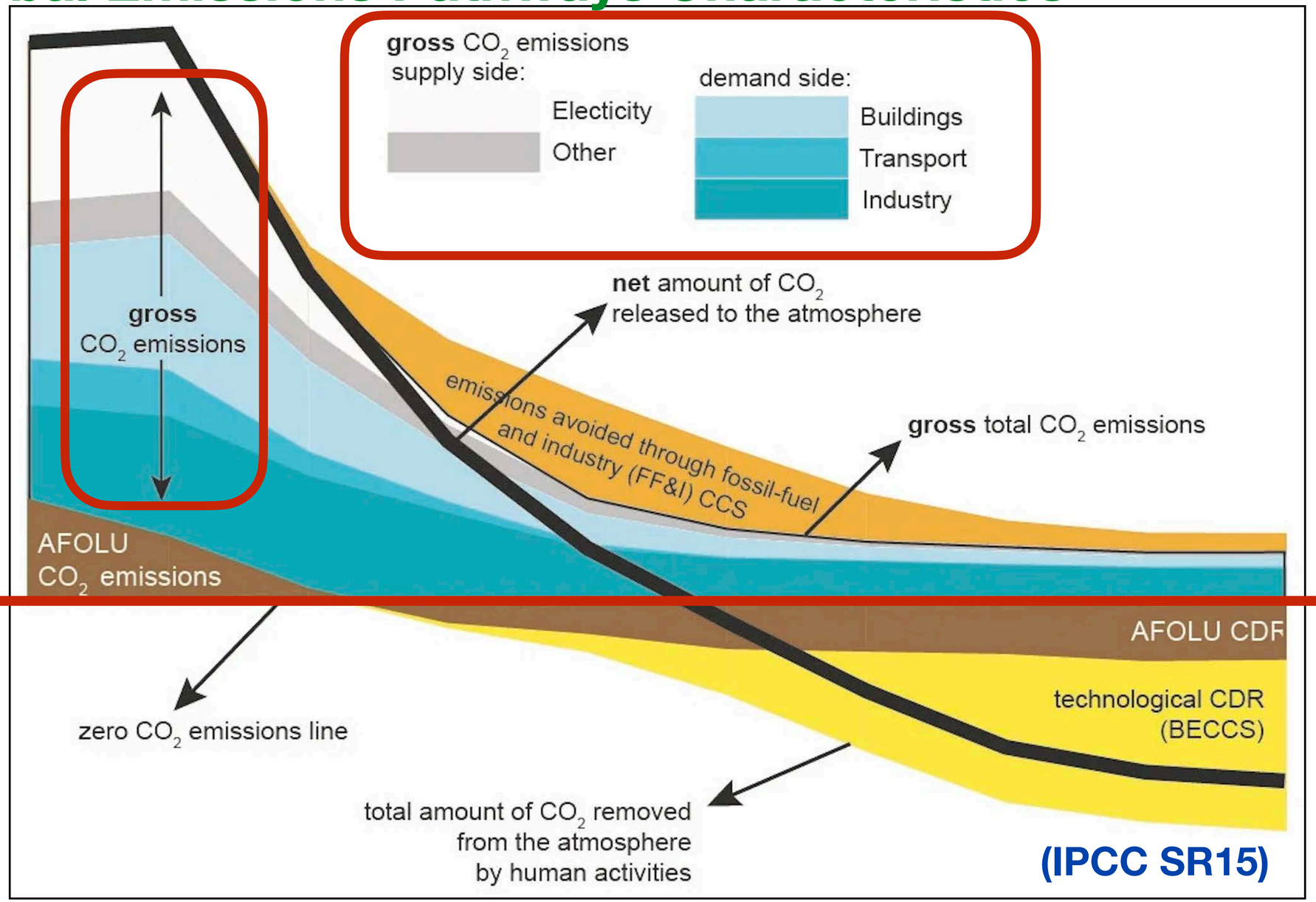

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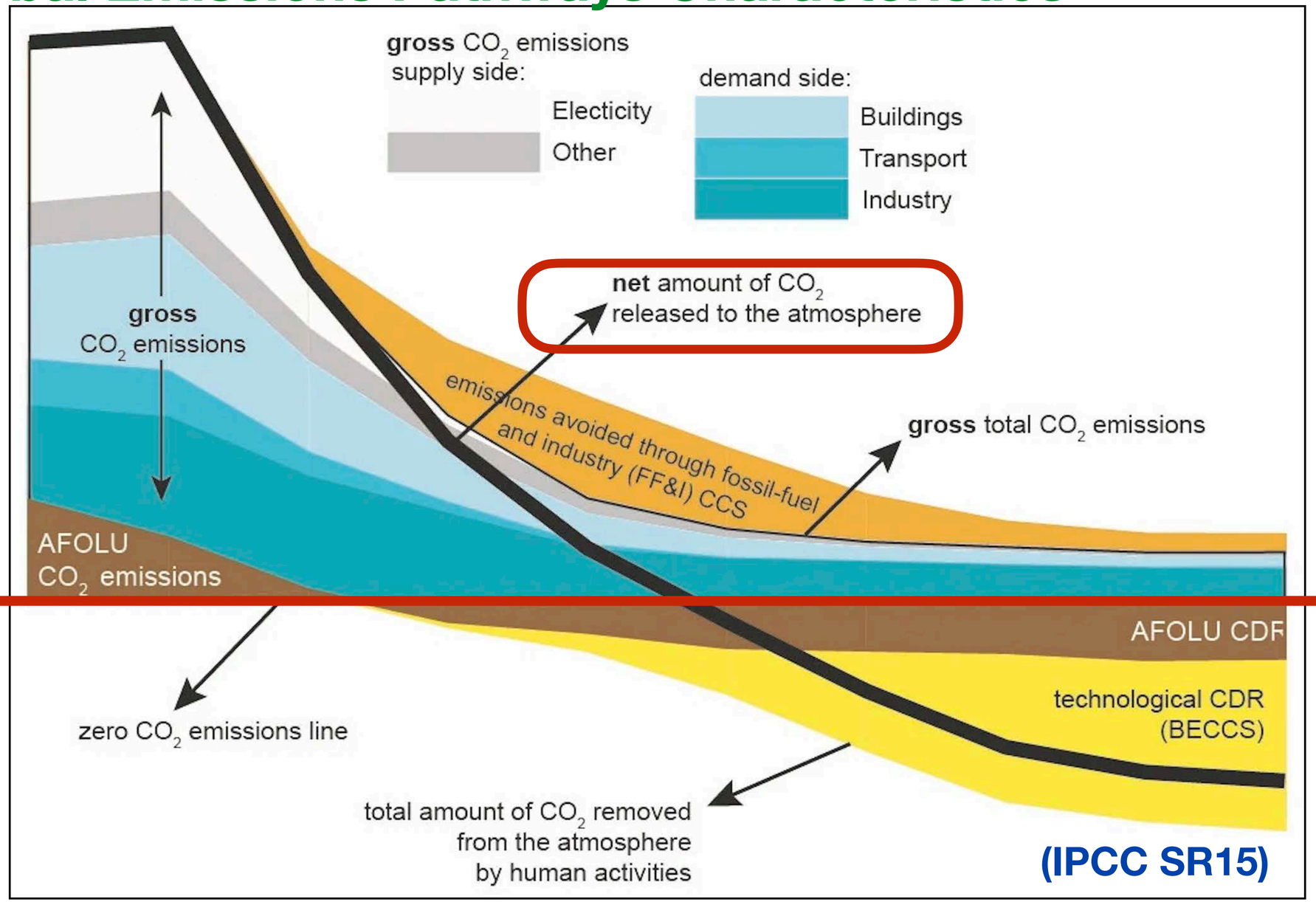

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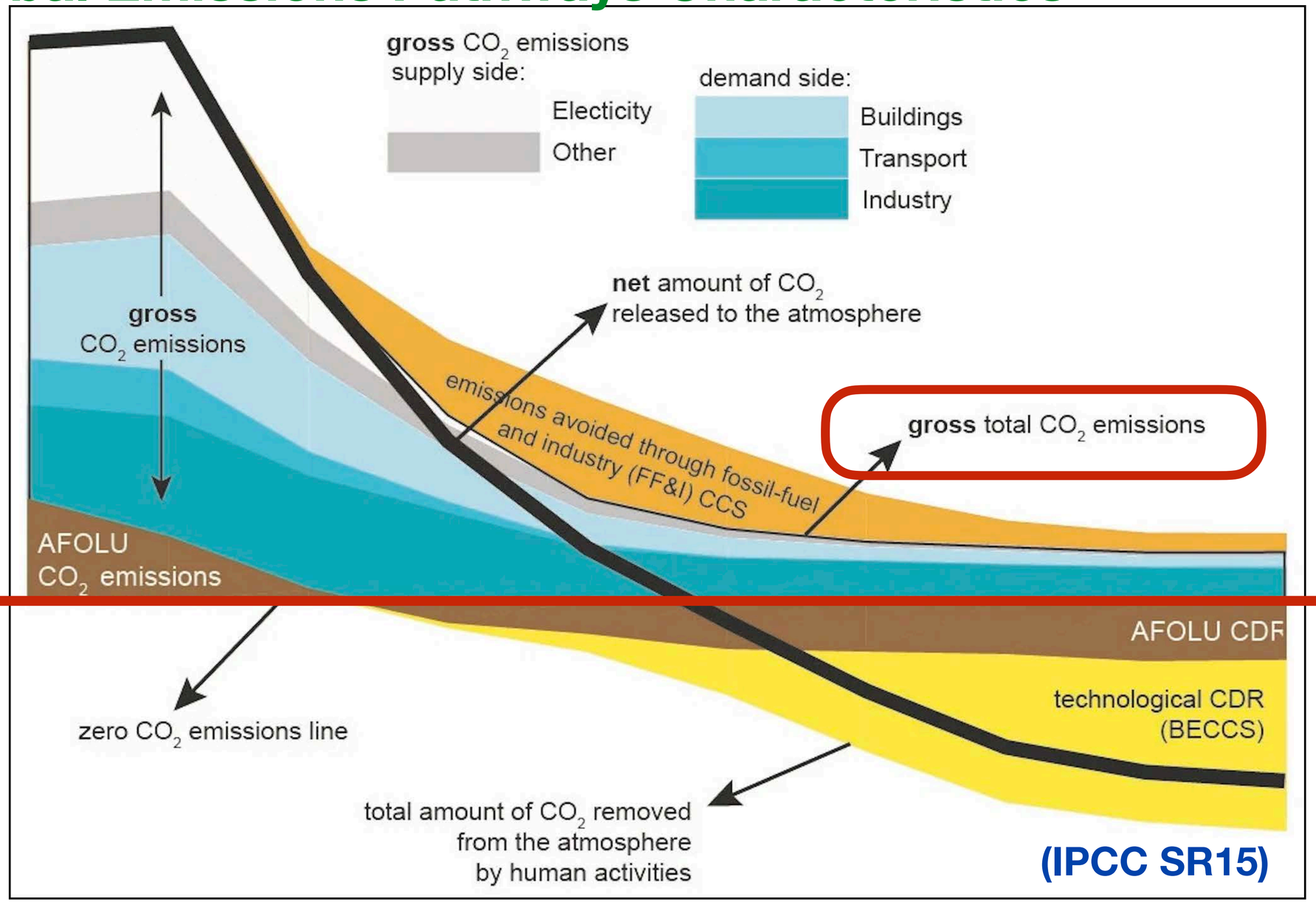

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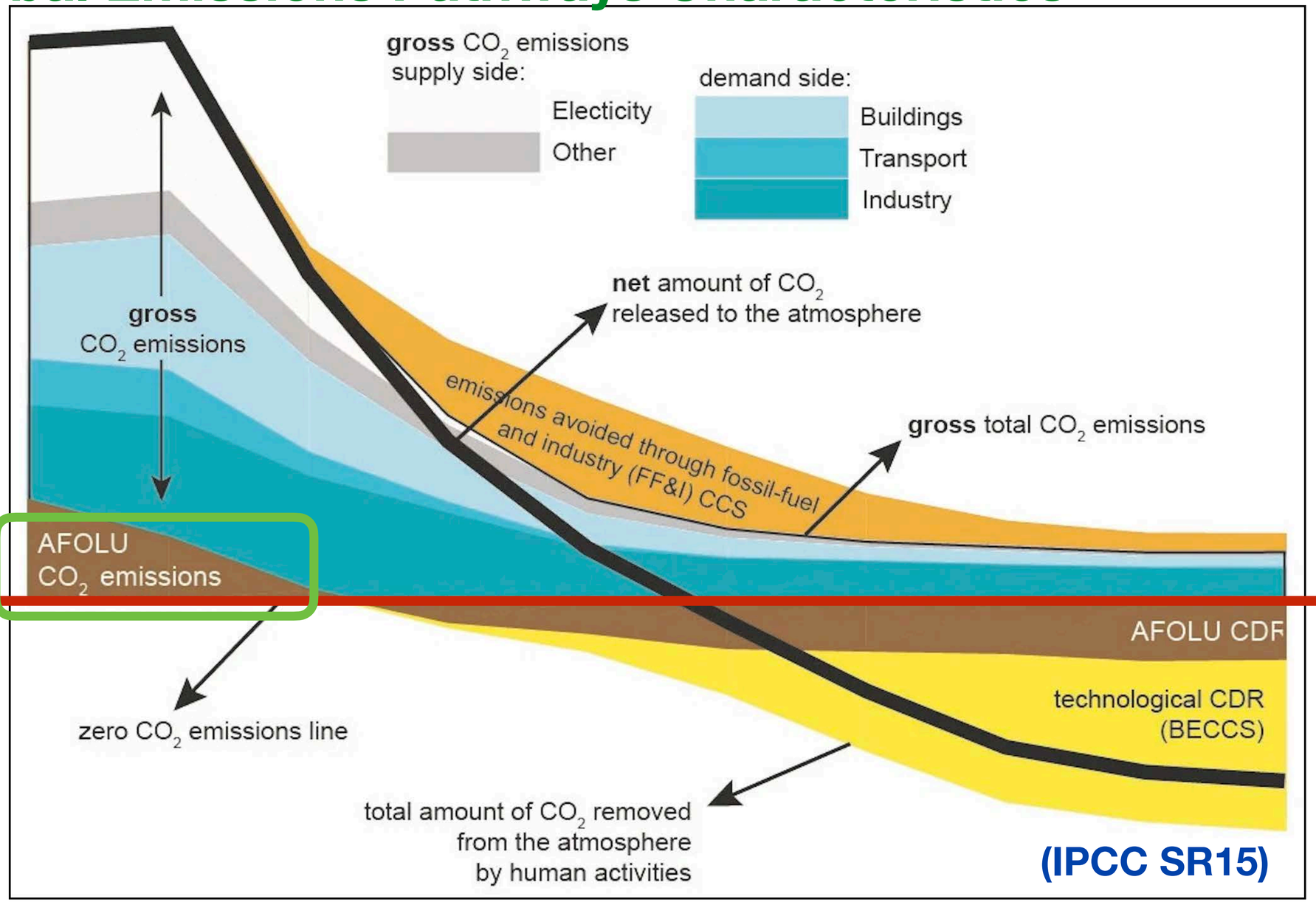

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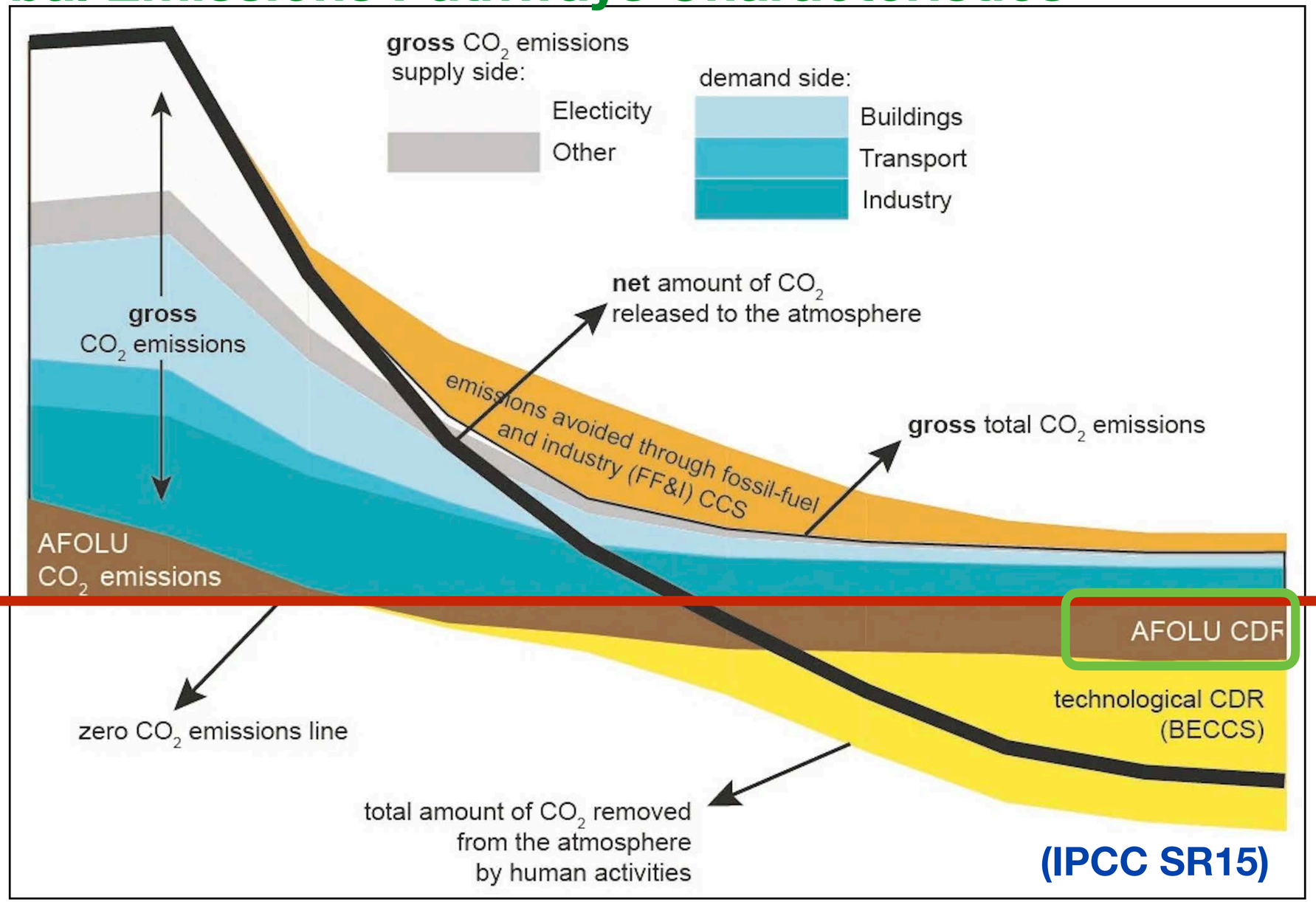

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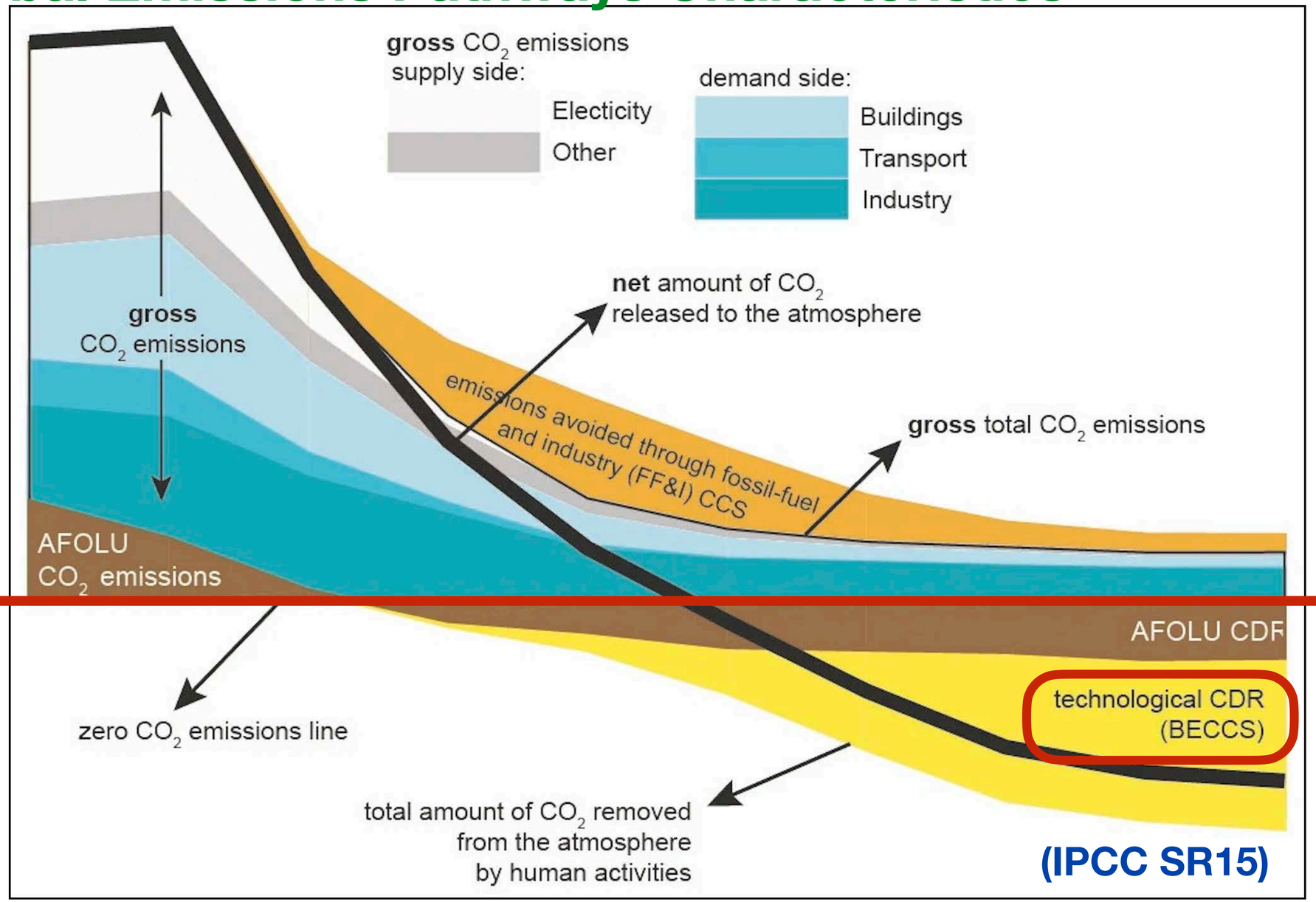

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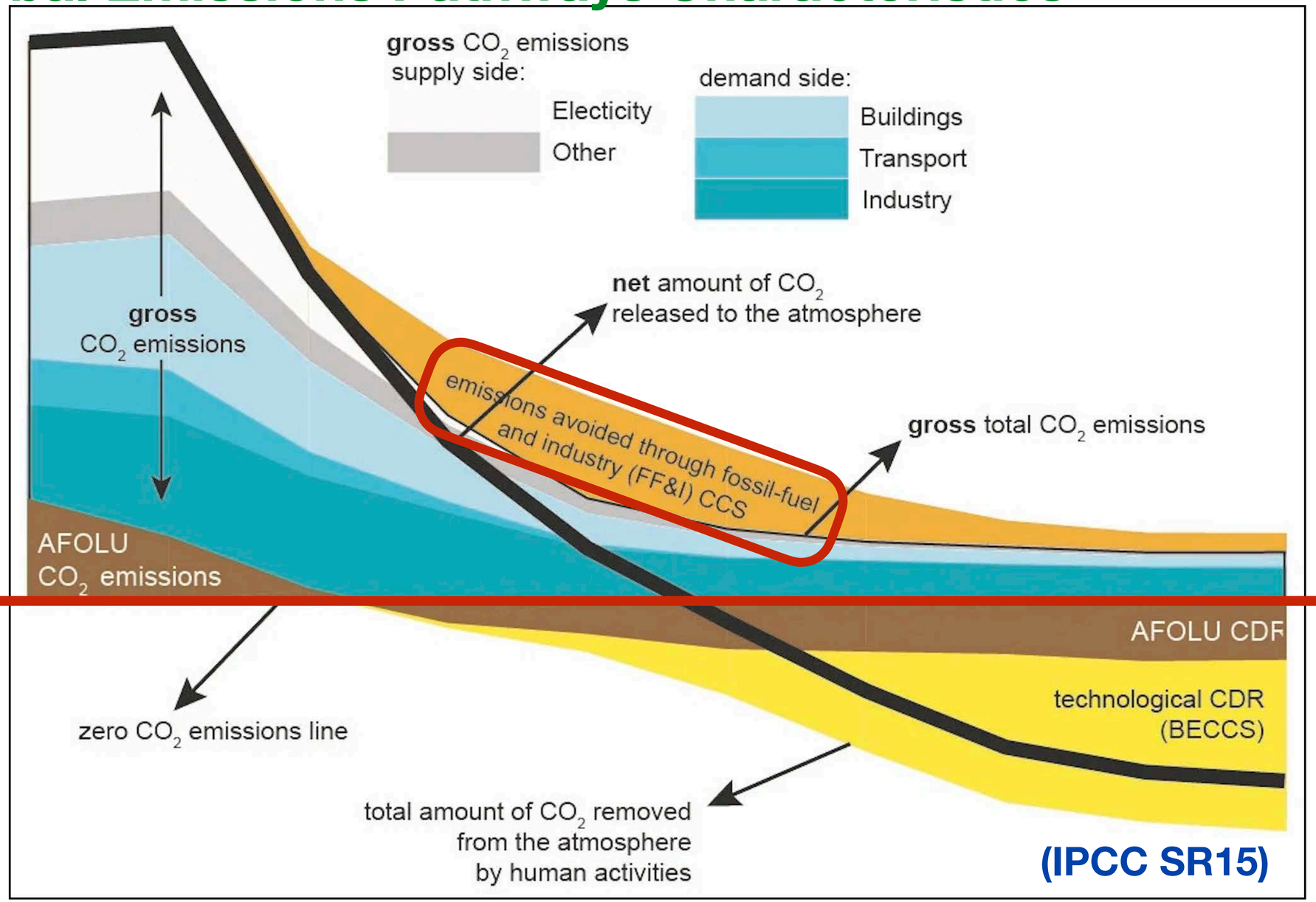

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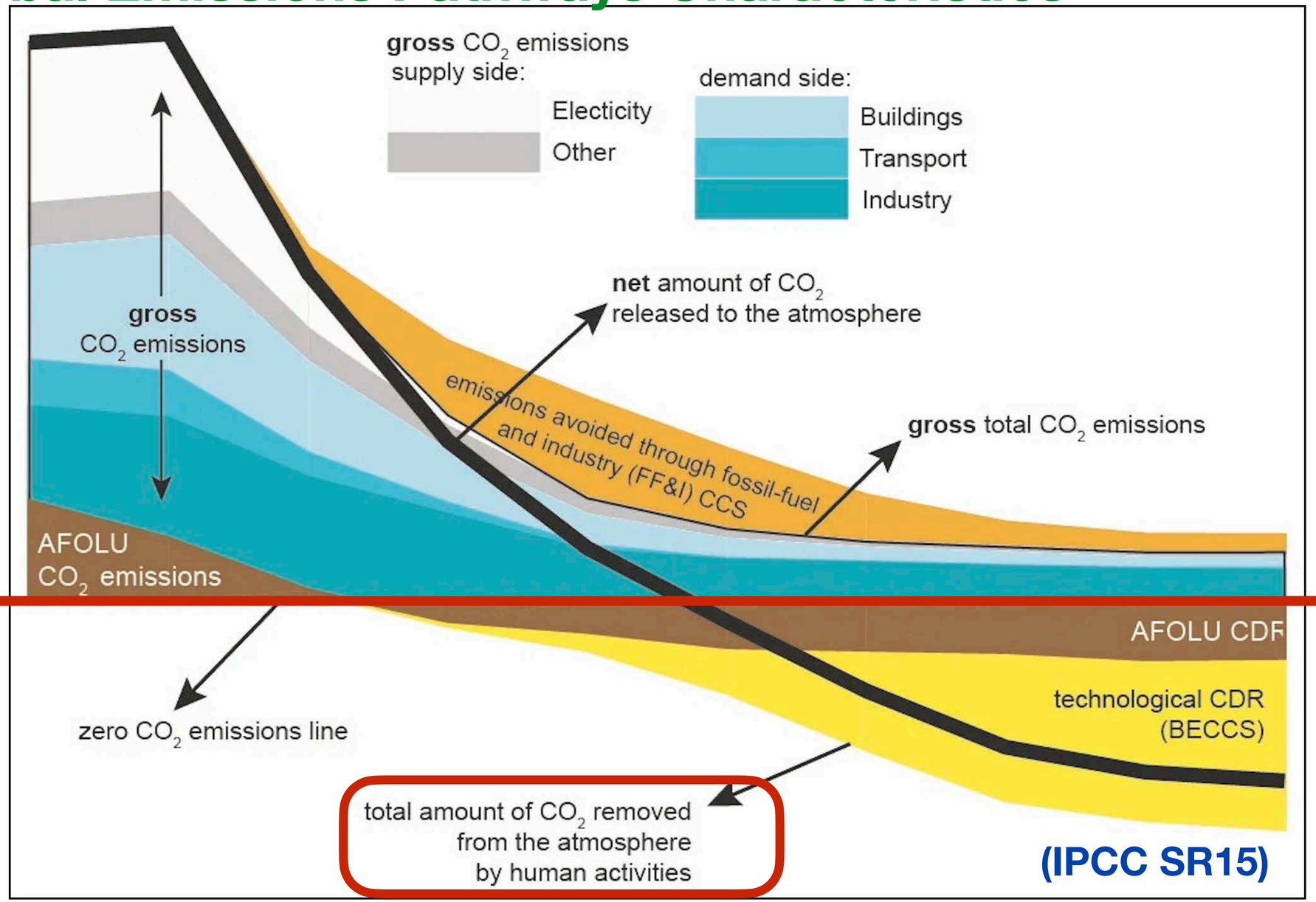

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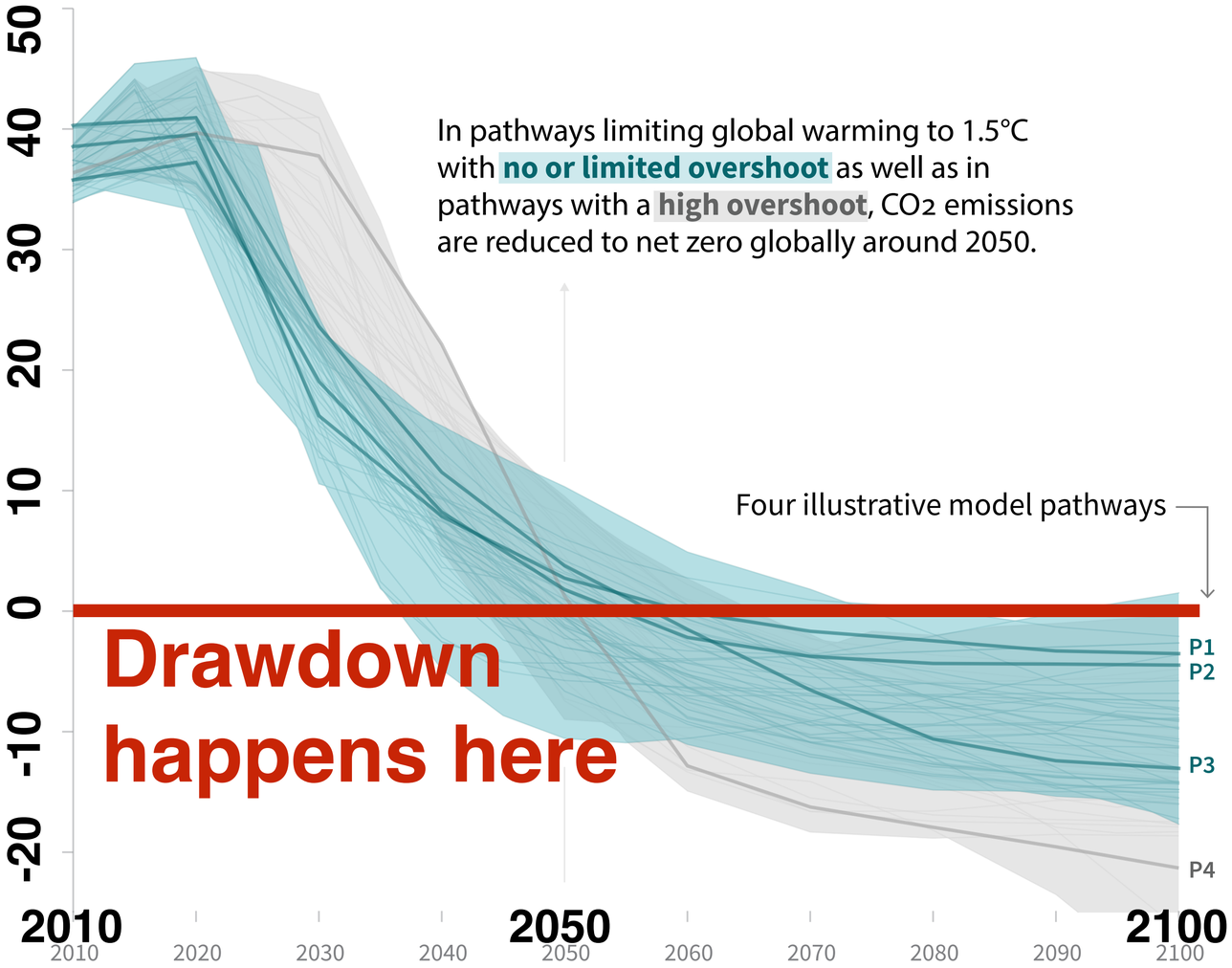
What pathways are consistent with 1.5ºC?

Global Emissions Pathways Characteristics

Global total net CO_2 emissions

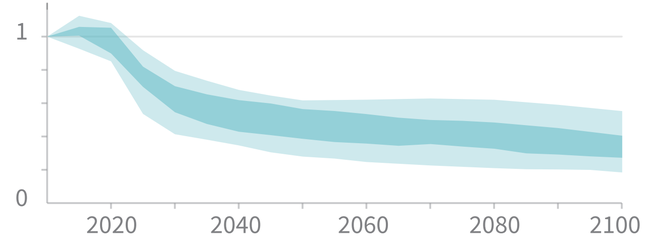
Billion tonnes of CO_2/yr



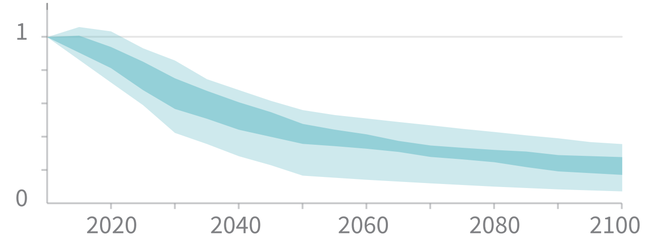
Non-CO_2 emissions relative to 2010

Emissions of non-CO_2 forcers are also reduced or limited in pathways limiting global warming to 1.5°C with **no or limited overshoot**, but they do not reach zero globally.

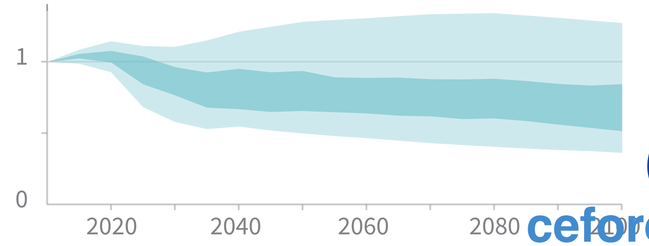
Methane emissions



Black carbon emissions



Nitrous oxide emissions



(IPCC SR15)

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1.3 Where are the planetary boundaries for Earth?

Planetary Boundaries

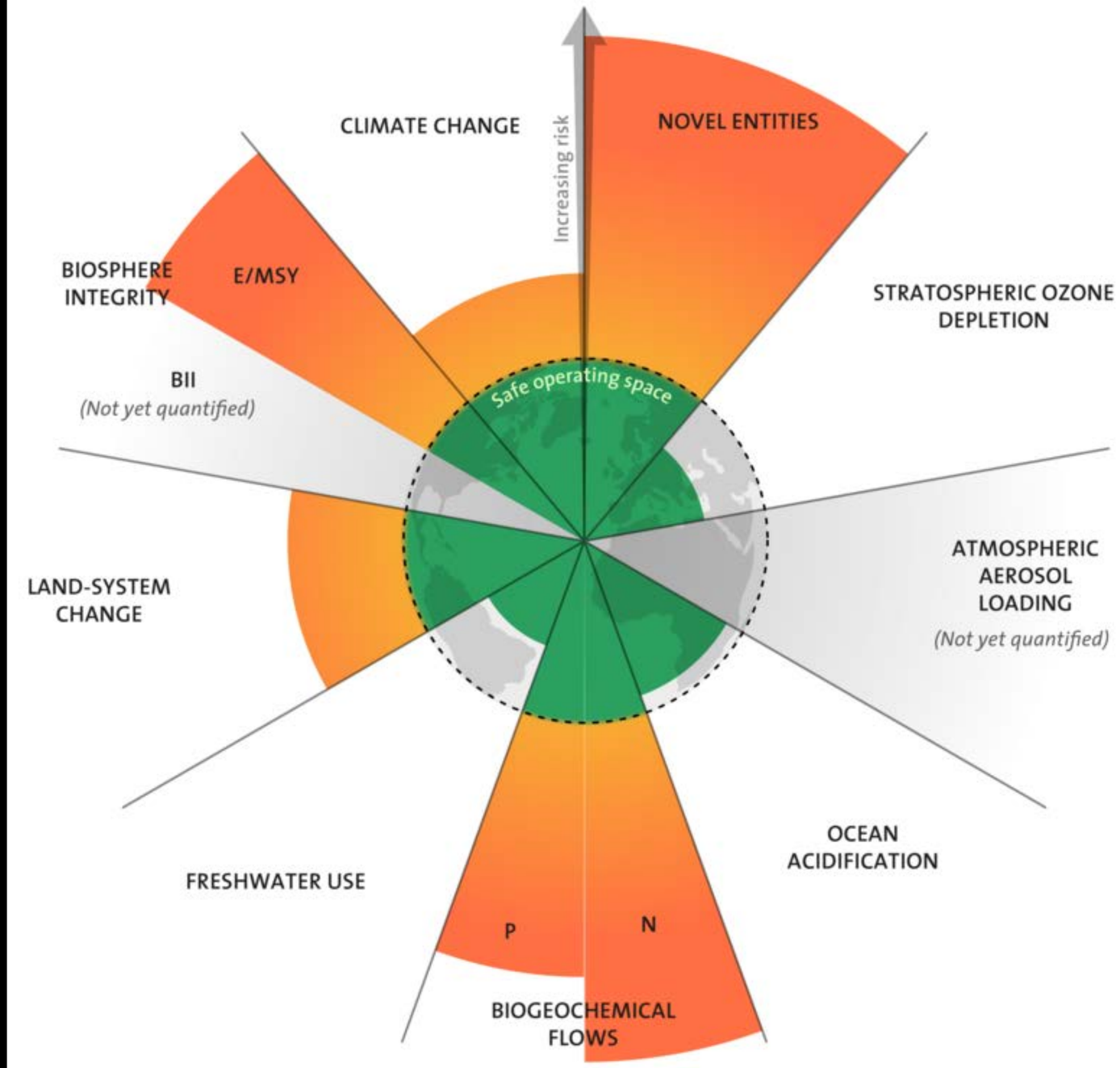
At what point might Earth's systems cease to function?

Led by Johan Rockström at the Stockholm Resilience Institute

https://en.wikipedia.org/wiki/Planetary_boundaries

(quote from: J.R.R. Tolkien, TFOTR)

ceforest@psu.edu / Earth Talks, 14 Mar 2022



why NetZero?

Some critical impacts that we know:

- Climate change is impacting (almost) the entire planet.
  - Atmosphere, Land, Oceans, Ice, Biosphere, Anthroposphere
- Land areas are warming faster than the oceans.
- The poles are warming faster than the tropics.
- It is disproportionately affecting the poor.
- We are seeing more climate related disasters globally.

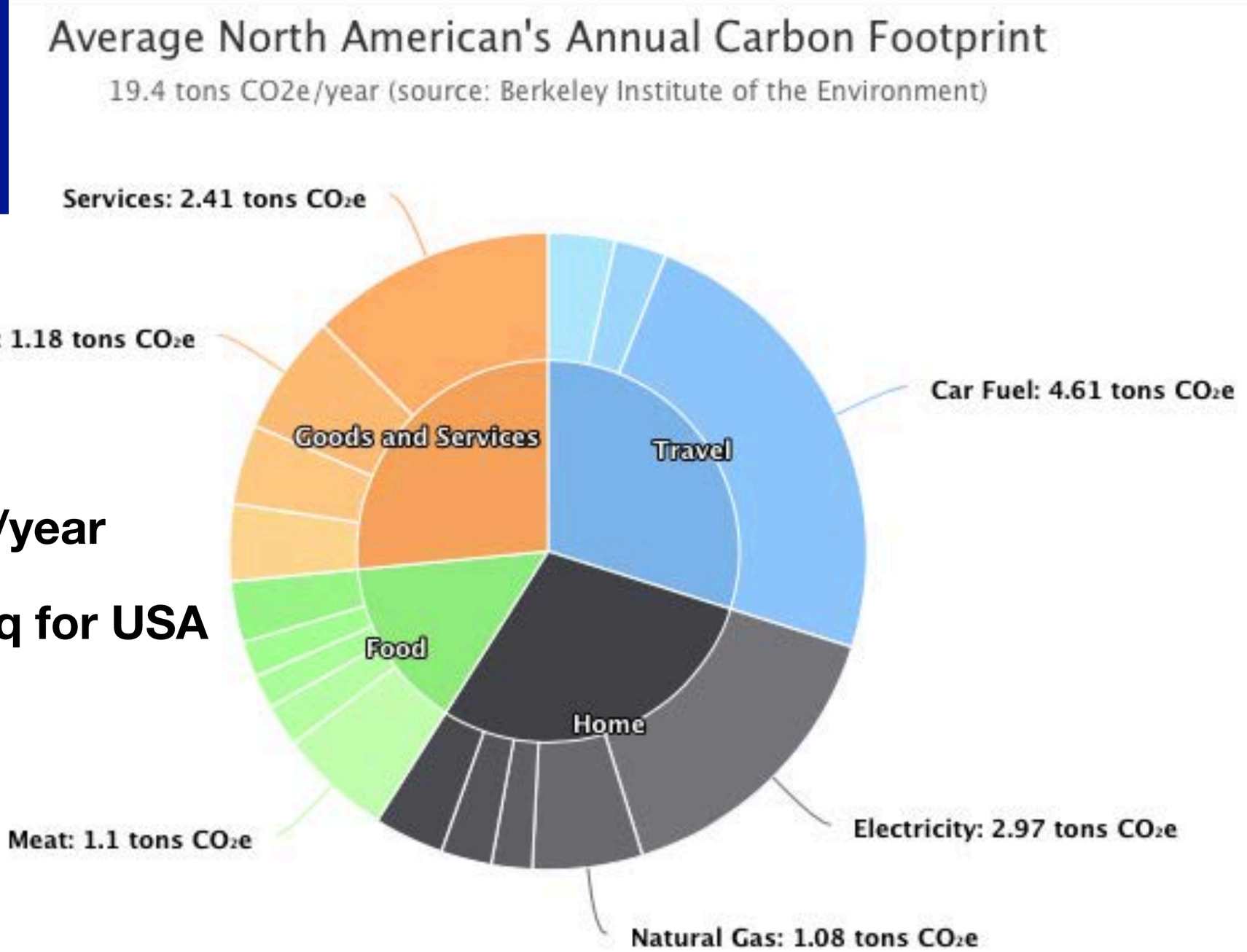
We expect these trends to continue and become more severe.

Getting to Net-Zero and Beyond

- Part 1: What are the stakes?
  - 1.1 Where are we now?
  - 1.2 What does NetZero really mean?
  - 1.3 Where are the planetary boundaries for Earth?
- **Part 2: What will it take?**
  - **2.1 Can we reduce emissions to Zero by 2050?**
  - **2.2 Can we go beyond net-zero with net carbon storage?**
- Part 3: What future do we choose? What stands in the way?

Part 2.1: Can we reduce?

Question 1:
How much CO_2-e do we generate?



Total per Person: 19.4 tons/year

Total for USA: ~6.4 $GtCO_2eq$ for USA

https://www.2degreesinstitute.org

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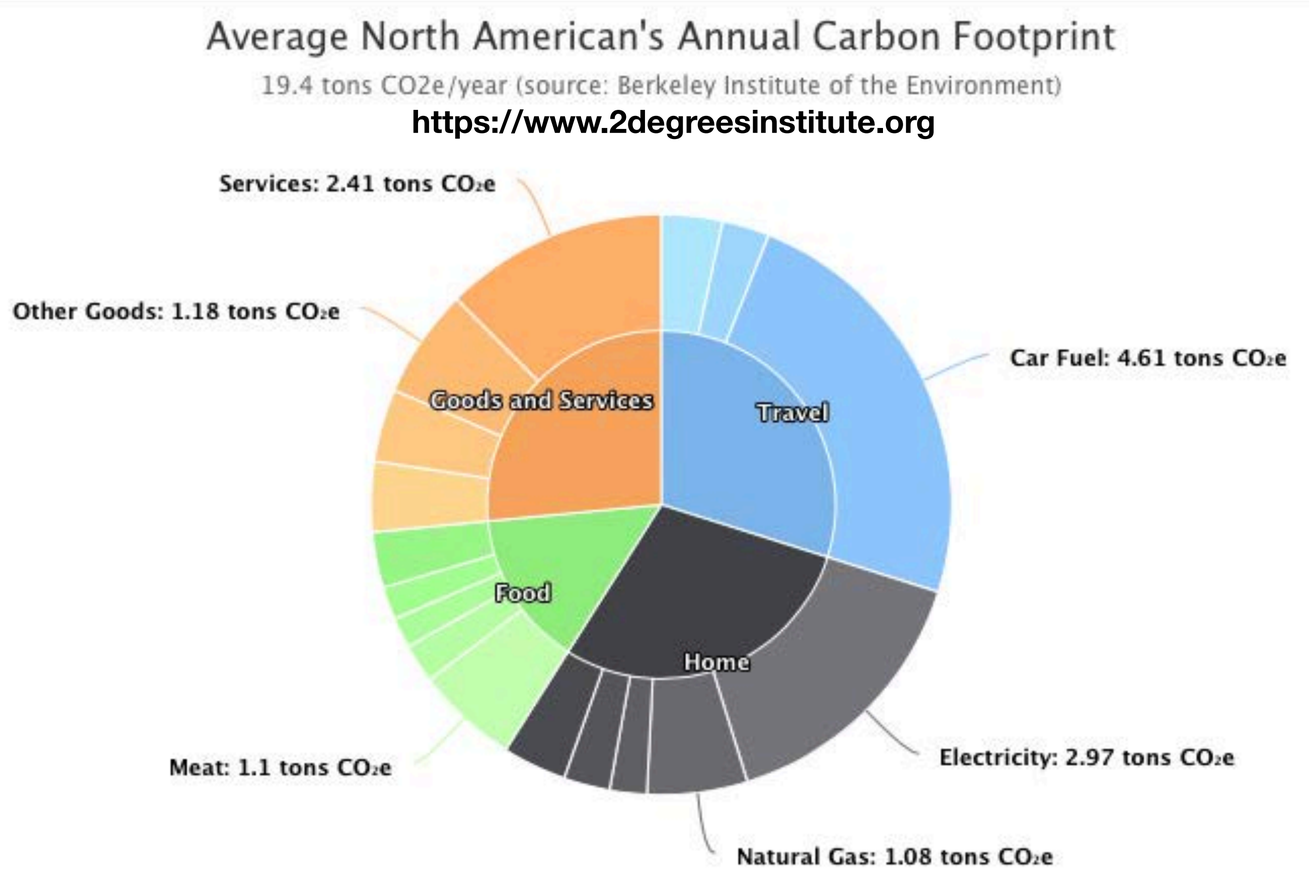

Total: (19.4 tons/year) X (US Population)
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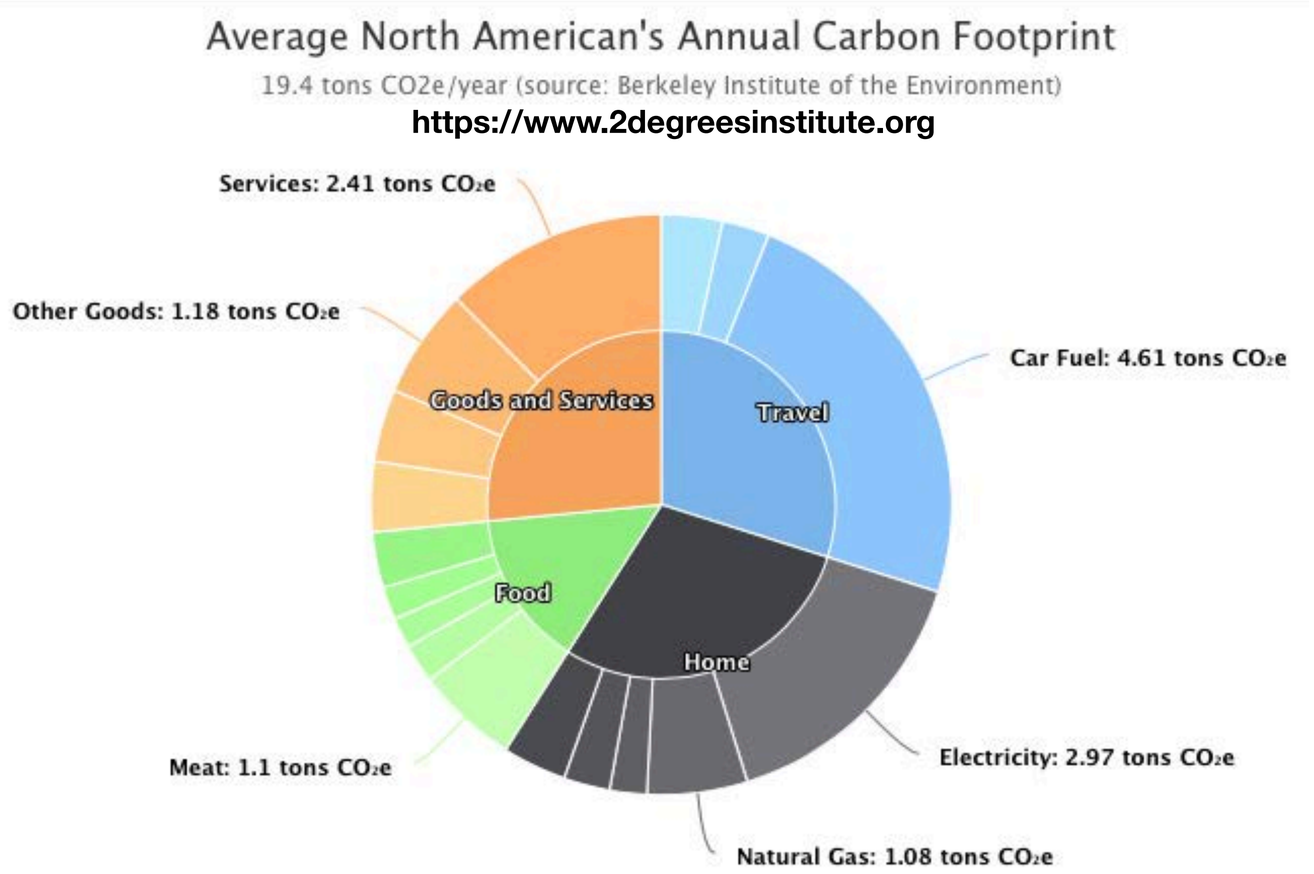

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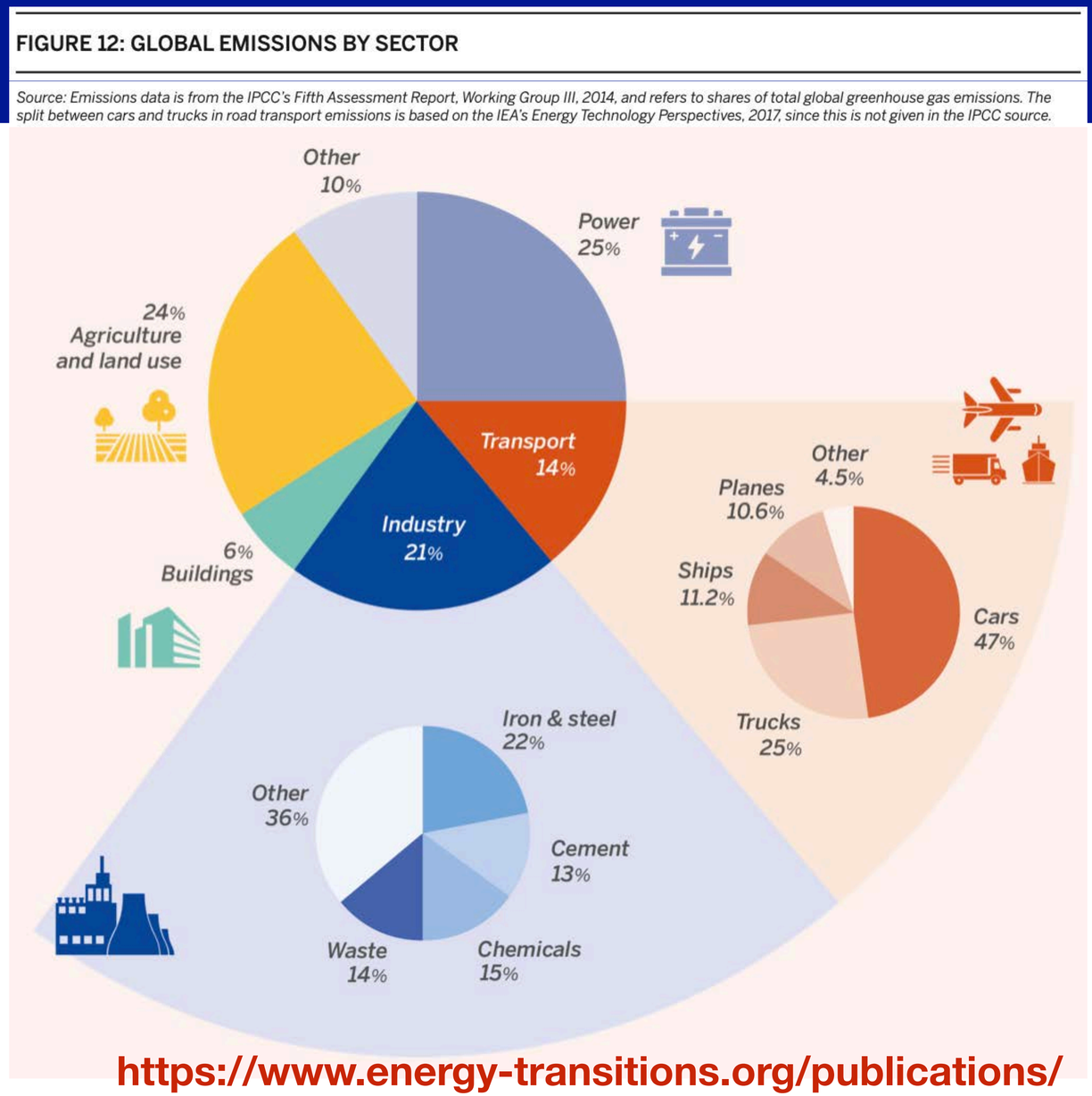

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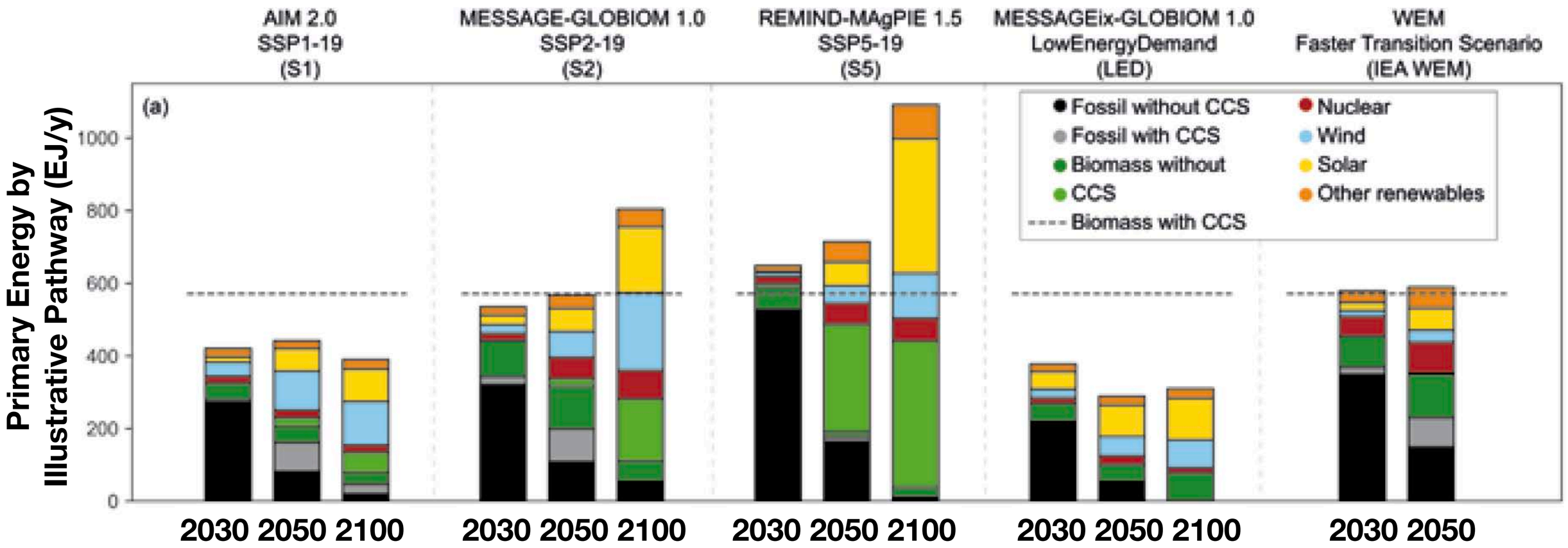
Question 2: What energy pathways get to NetZero and beyond ?

From the IPCC Special Report on Global Warming of 1.5ºC, scenarios showing Energy Production per Year by Fuel Source



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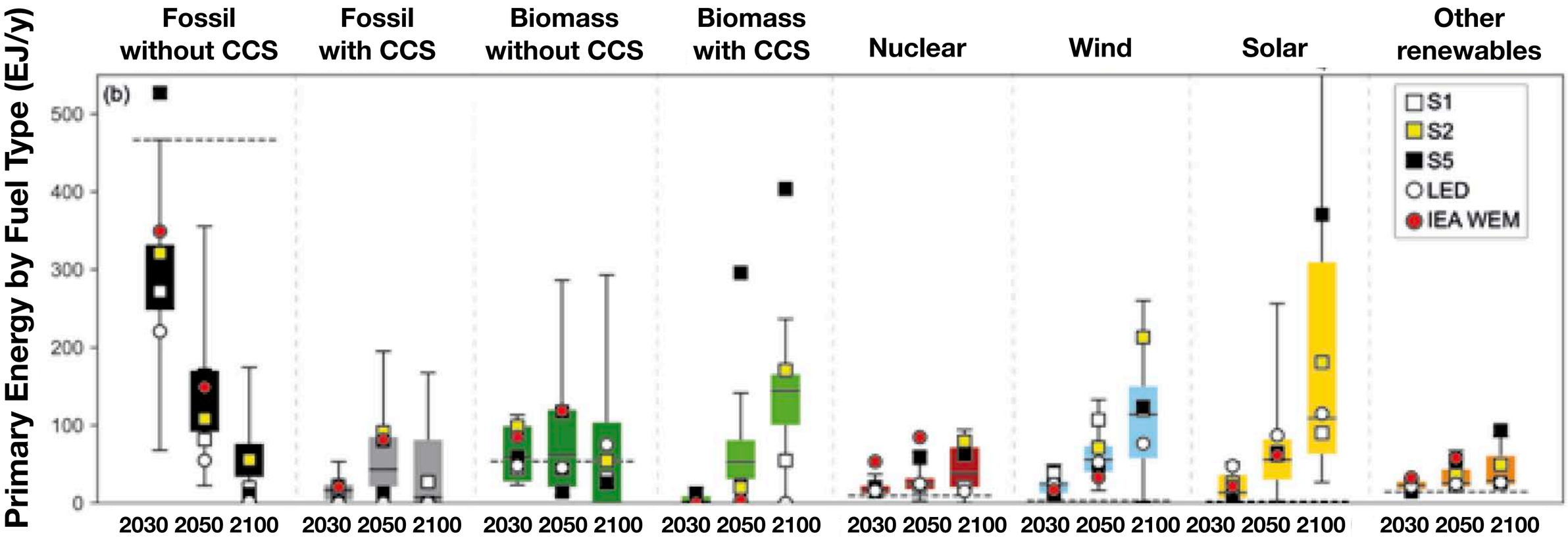
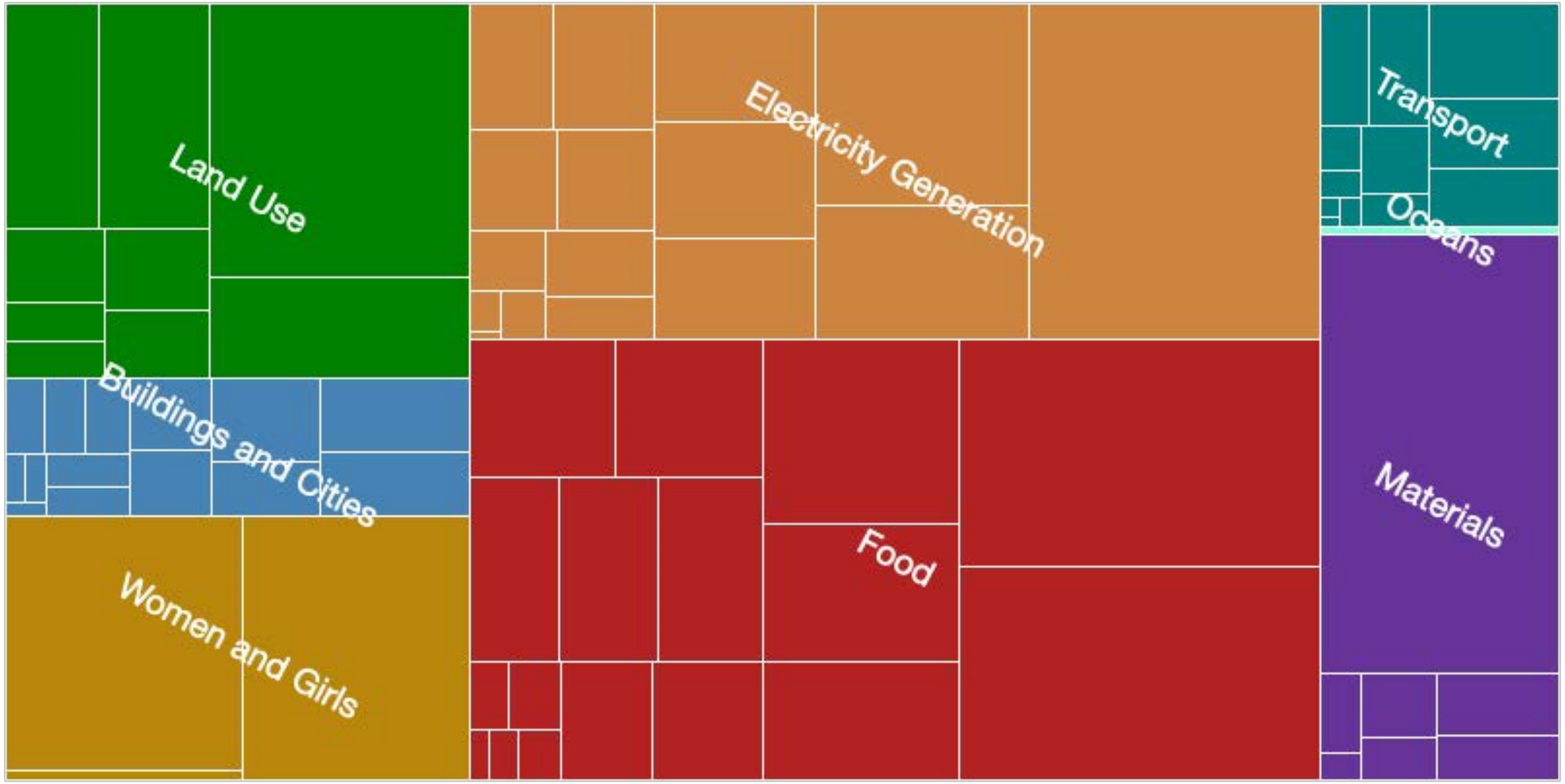


What is the plan to reach NetZero based on: Reduce Source, Support Sinks, Improve Society?



Project Drawdown's 100 Solutions by Sector (2017)

ceforest@psu.edu

The Solutions

Minimum CO_2-eq (Gt) reduced/sequestered (2020-2050)

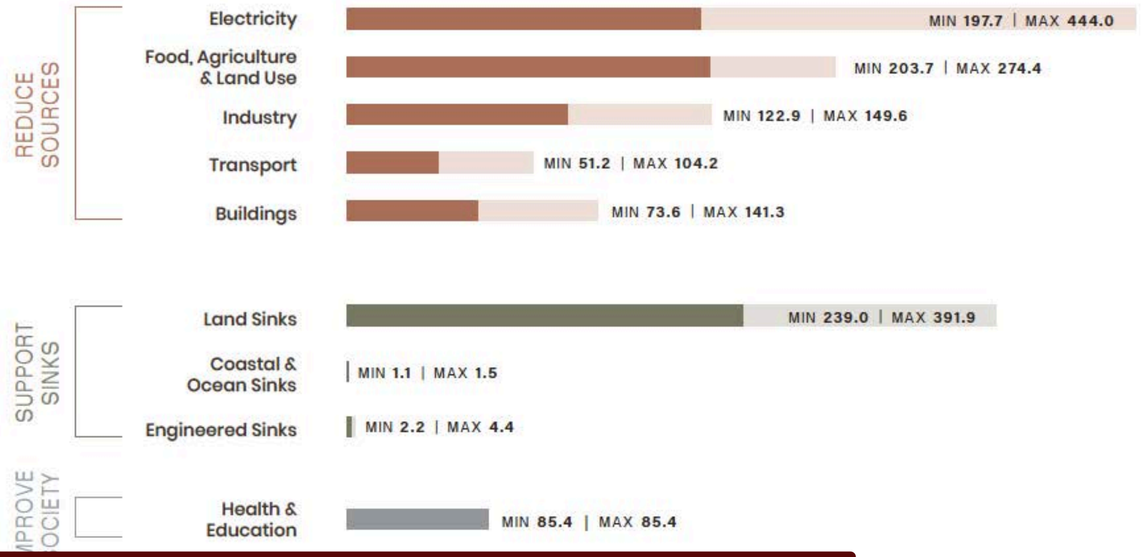
Maximum CO_2-eq (Gt) reduced/sequestered (2020-2050)

X / Y = Min / Max CO_2-eq (Gt) reduced/sequestered (2020-2050)

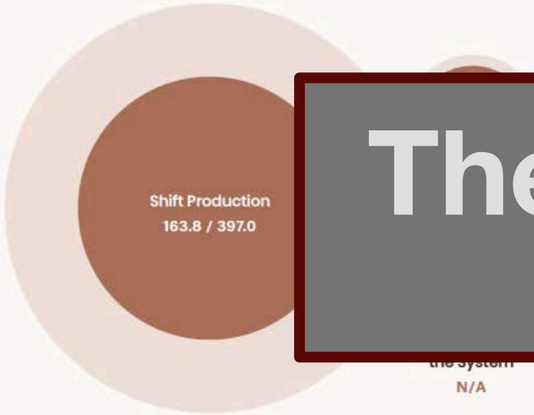
The Drawdown Solutions Framework organizes climate solutions by sector and by subgroup, within three overarching areas of action. Here, you see the potential emissions impact of each sector, as well as the solution subgroups therein. Using two different scenarios of solution implementation, we derived the minimum and maximum impact shown here. (See more on scenarios below.)

Reduce Sources

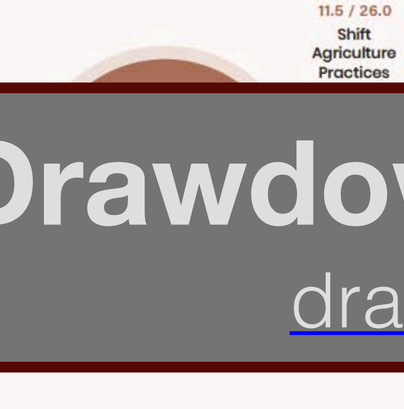
TOTAL: MIN **649.2** | MAX **1113.5**



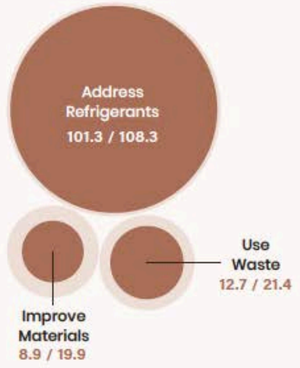
Electricity



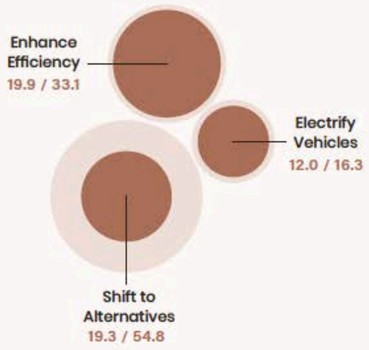
Food, Agriculture & Land Use



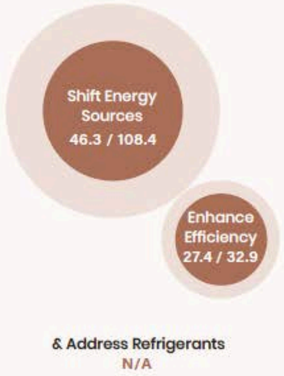
Industry

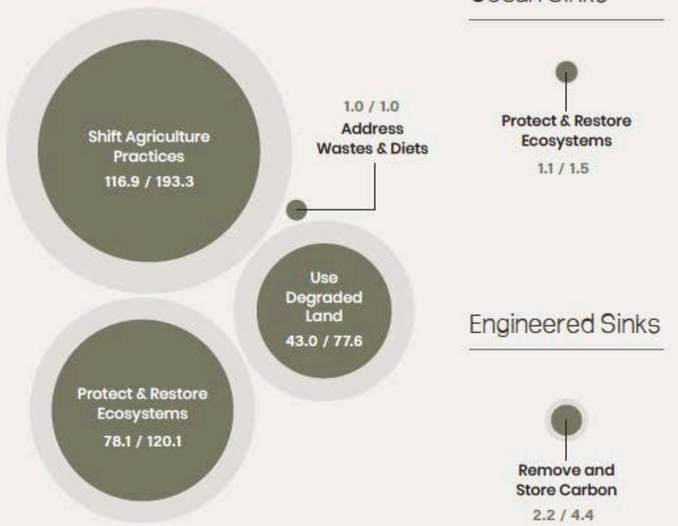


Transport



Buildings





Ocean Sinks

Engineered Sinks

Health & Education

The Drawdown Review (2020)

drawdown.org

ceforest@psu.edu

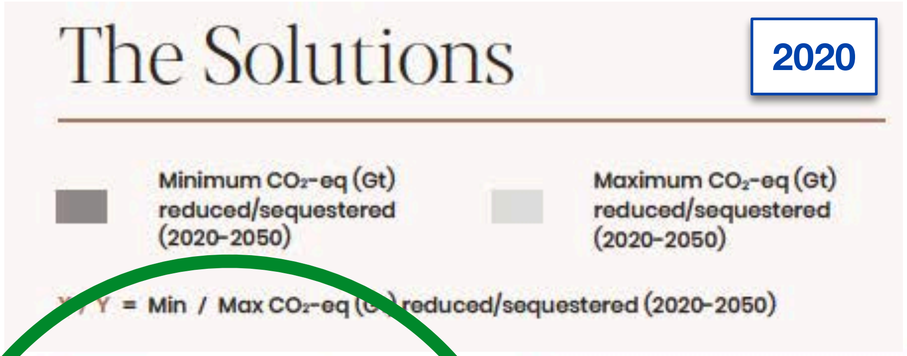
https://www.drawdown.org

The Drawdown Review (2020)

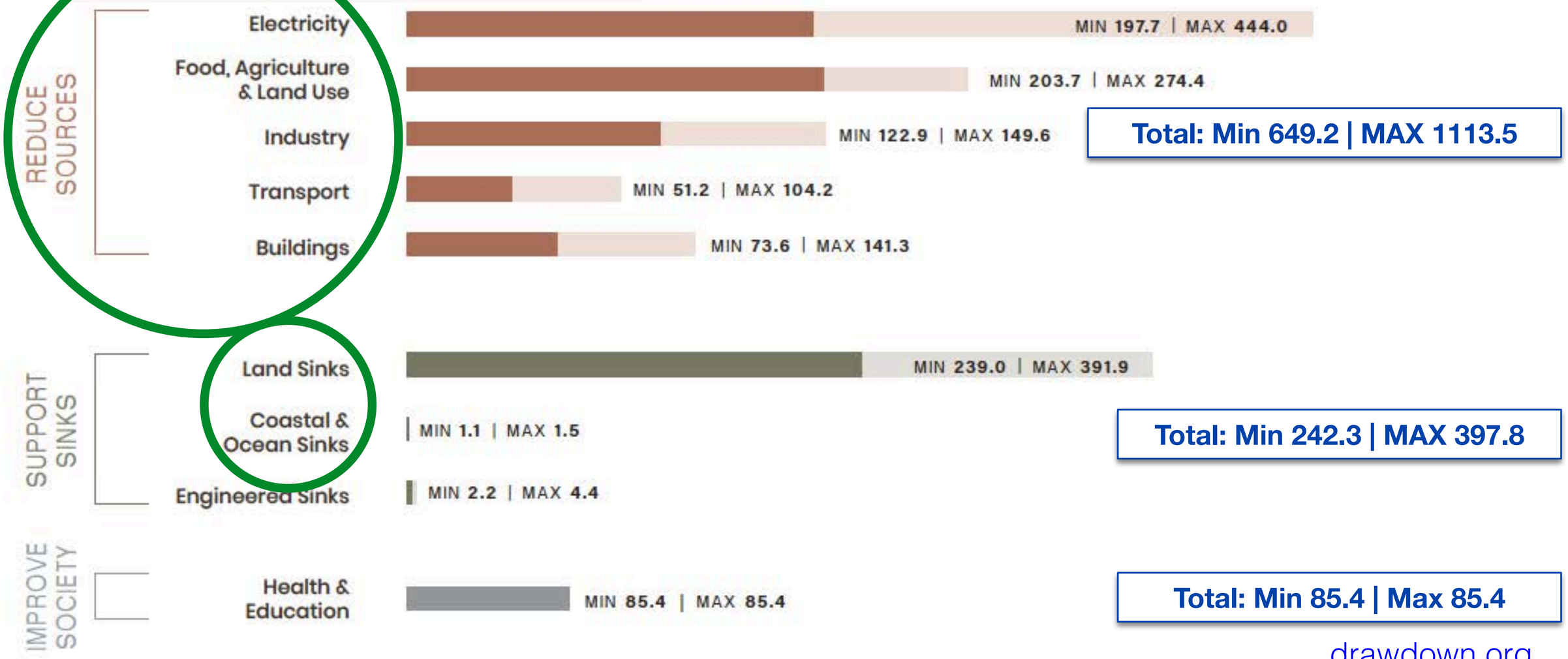
drawdown.org
ceforest@psu.edu

The Solutions

2020



Grand Total: Min 976.9 | MAX 1596.7
(in $GtCO_2$-eq over 2020-2050 period)



Total: Min 649.2 | MAX 1113.5

Total: Min 242.3 | MAX 397.8

Total: Min 85.4 | Max 85.4

drawdown.org

ceforest@psu.edu


PennState

DRAWDOWN

U.S. DEPARTMENT OF ENERGY

Office of Science

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Conclusions:

- We know we can emit up to a limit.
- We know the limit sets the global temperature.
- We know the impacts of climate change will get worse.
- We know there are solutions.

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Conclusions:

- We know we can emit up to a limit.
- We know the limit sets the global temperature.
- We know the impacts of climate change will get worse.
- We know there are solutions.

So, it's time to get started on Part 3:

- What future should we choose?
- What values do we use to make those choices?
- What stands in our way to make this work?

PennState | DRAWDOWN

MIT

NSF

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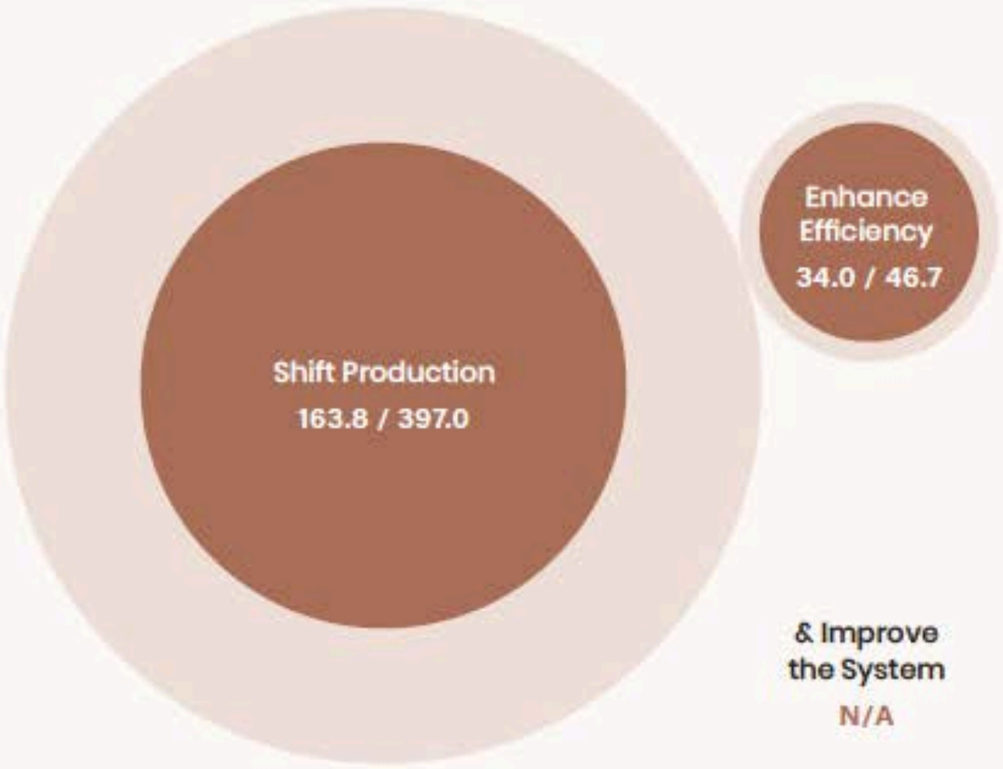
Extra Slides

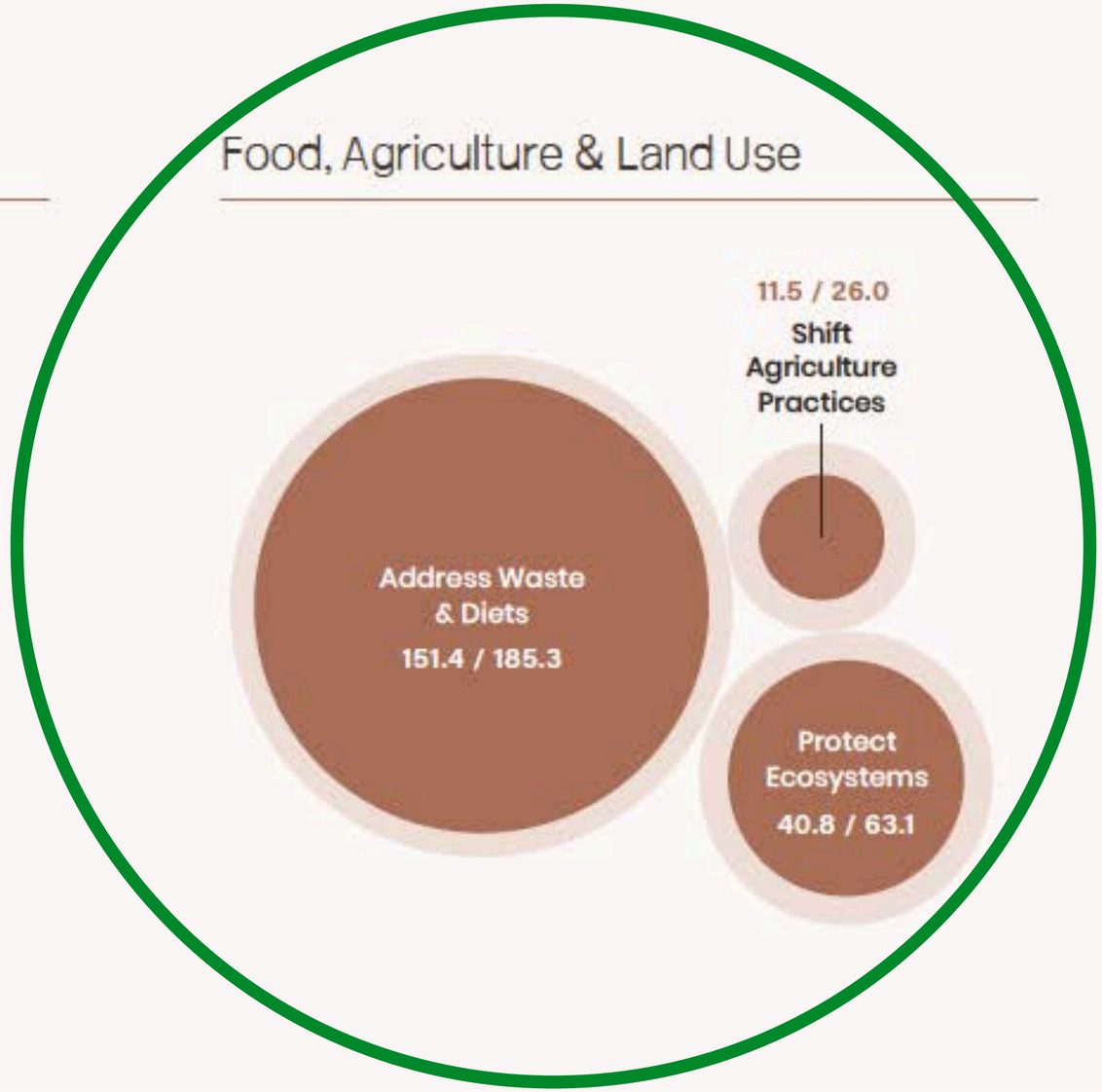
Reduce Sources

TOTAL: MIN **649.2** | MAX **1113.5**

Electricity



Food, Agriculture & Land Use



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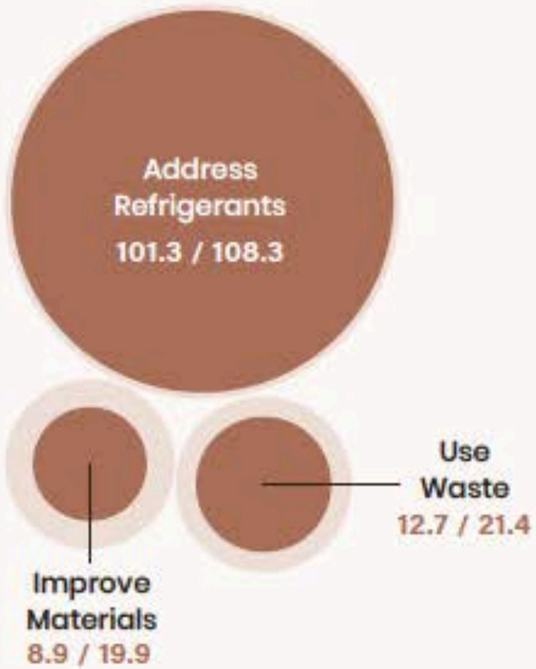
Reduce Sources

TOTAL: MIN 649.2 | MAX 1113.5

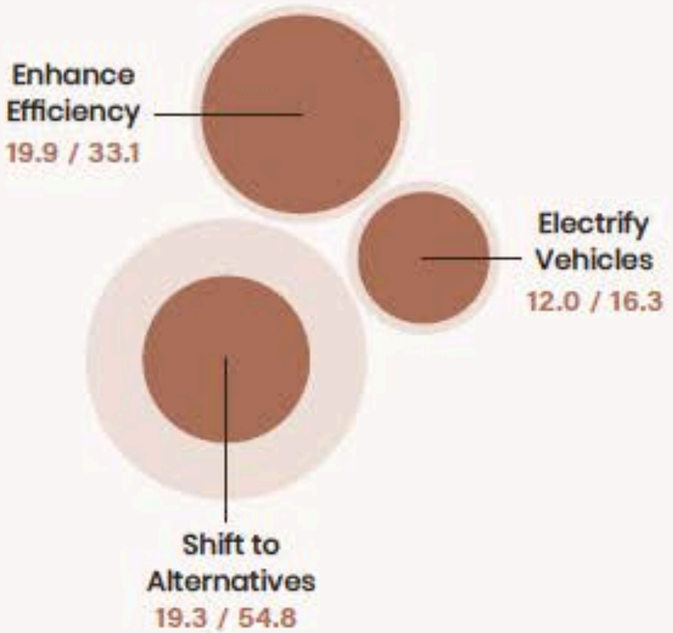
Electricity

Food, Agriculture & Land Use

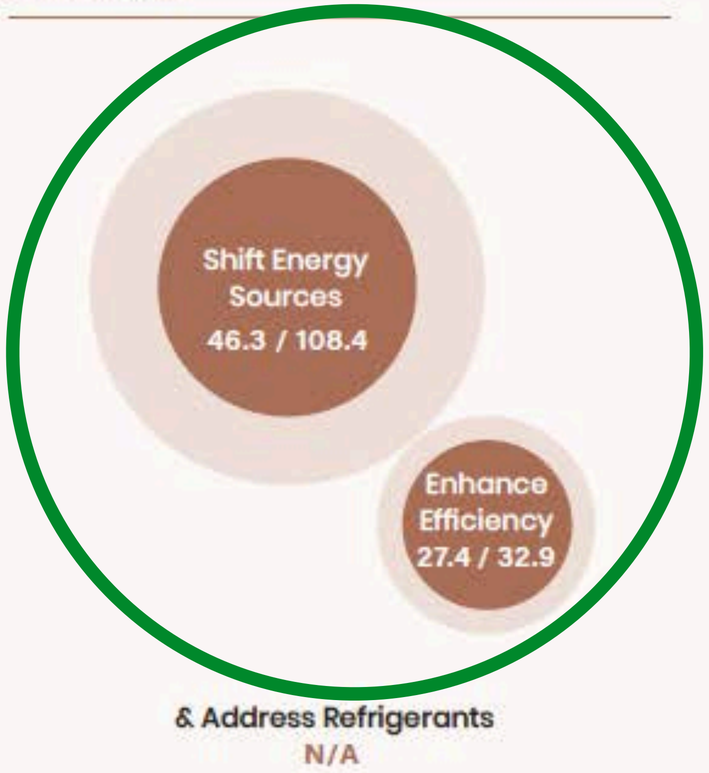
Industry



Transport



Buildings



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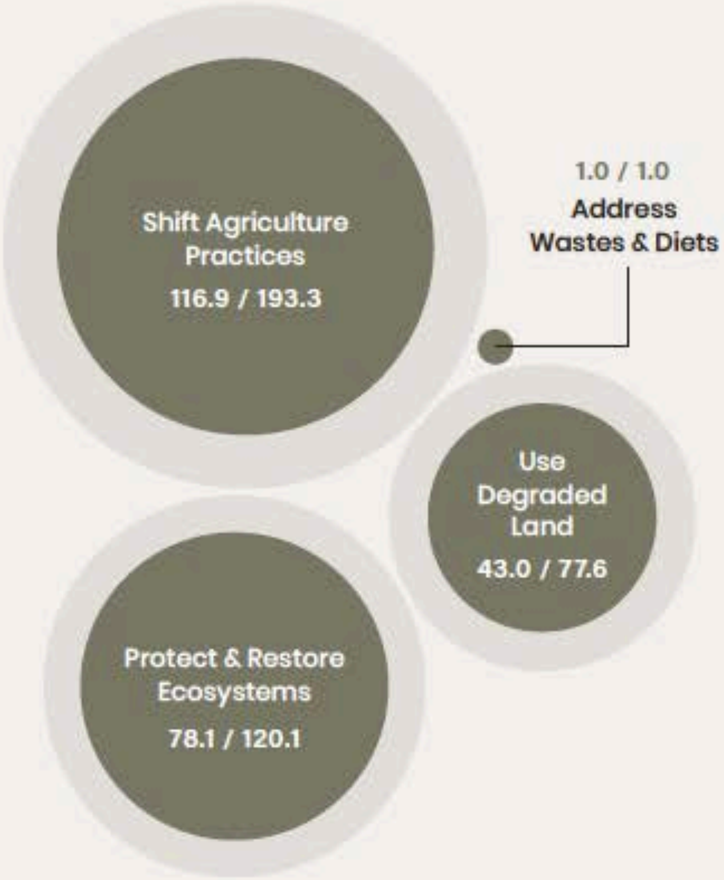
Support Sinks

TOTAL: MIN 242.3 | MAX 397.8

Land Sinks



Coastal & Ocean Sinks

Engineered Sinks

Improve Society

TOTAL: MIN 85.4 | MAX 85.4

Health & Education

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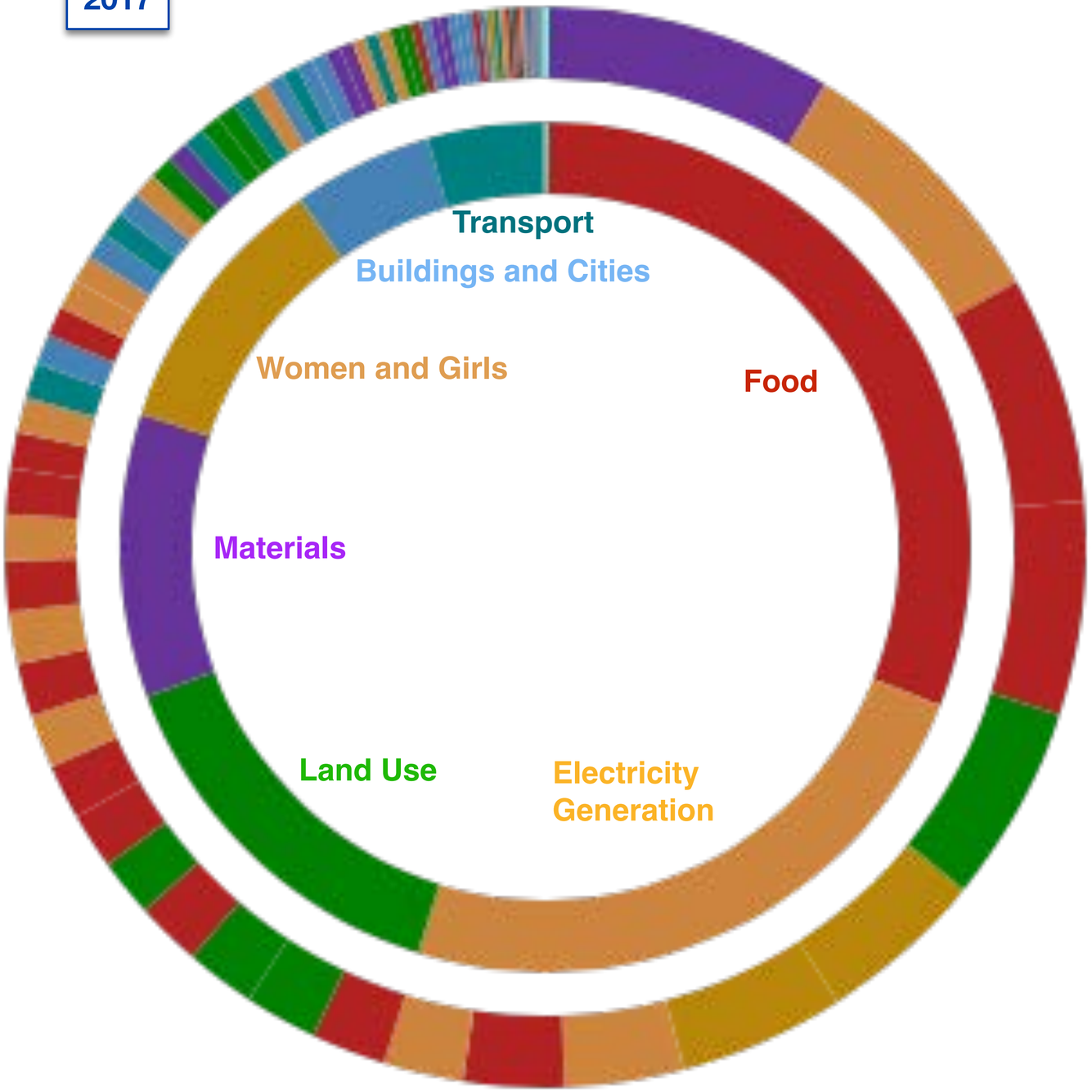
ceforest@psu.edu

2017



2020

The Solutions

Minimum CO_2-eq (Gt) reduced/sequestered (2020-2050)

Maximum CO_2-eq (Gt) reduced/sequestered (2020-2050)

X / Y = Min / Max CO_2-eq (Gt) reduced/sequestered (2020-2050)

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Grand Total: Min 976.9 | MAX 1596.7

REDUCE SOURCES

Electricity	MIN 197.7 | MAX 444.0
Food, Agriculture & Land Use	MIN 203.7 | MAX 274.4
Industry	MIN 122.9 | MAX 149.6
Transport	MIN 51.2 | MAX 104.2
Buildings	MIN 73.6 | MAX 141.3

Total: Min 649.2 | MAX 1113.5

SUPPORT SINKS

Land Sinks	MIN 239.0 | MAX 391.9
Coastal & Ocean Sinks	MIN 1.1 | MAX 1.5
Engineered Sinks	MIN 2.2 | MAX 4.4

Total: Min 242.3 | MAX 397.8

IMPROVE SOCIETY

Health & Education	MIN 85.4 | MAX 85.4

Total: Min 85.4 | Max 85.4

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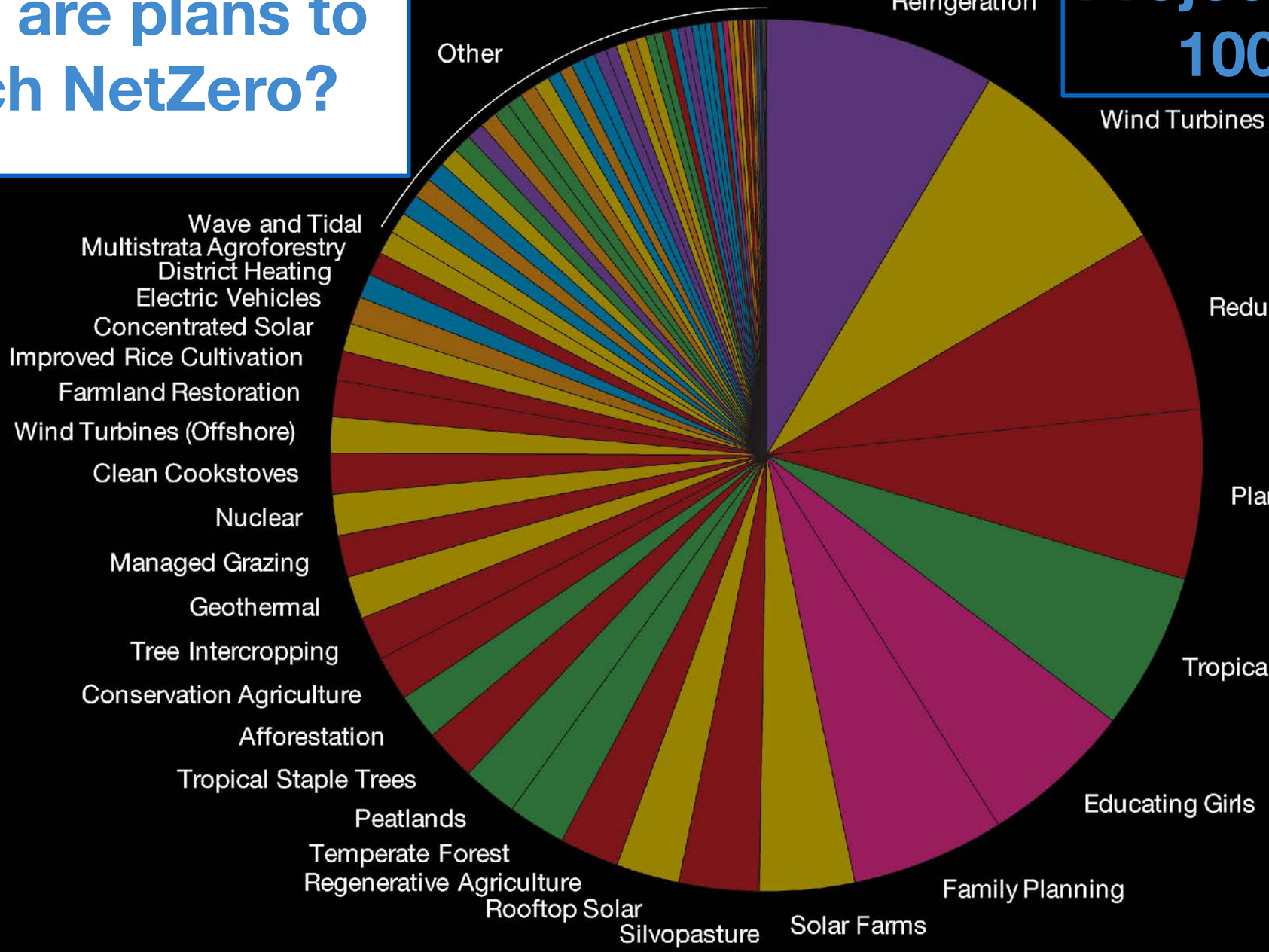
What are plans to reach NetZero?

Project Drawdown's 100 Solutions

c. 2017



Replace
Reduce
Biosequester

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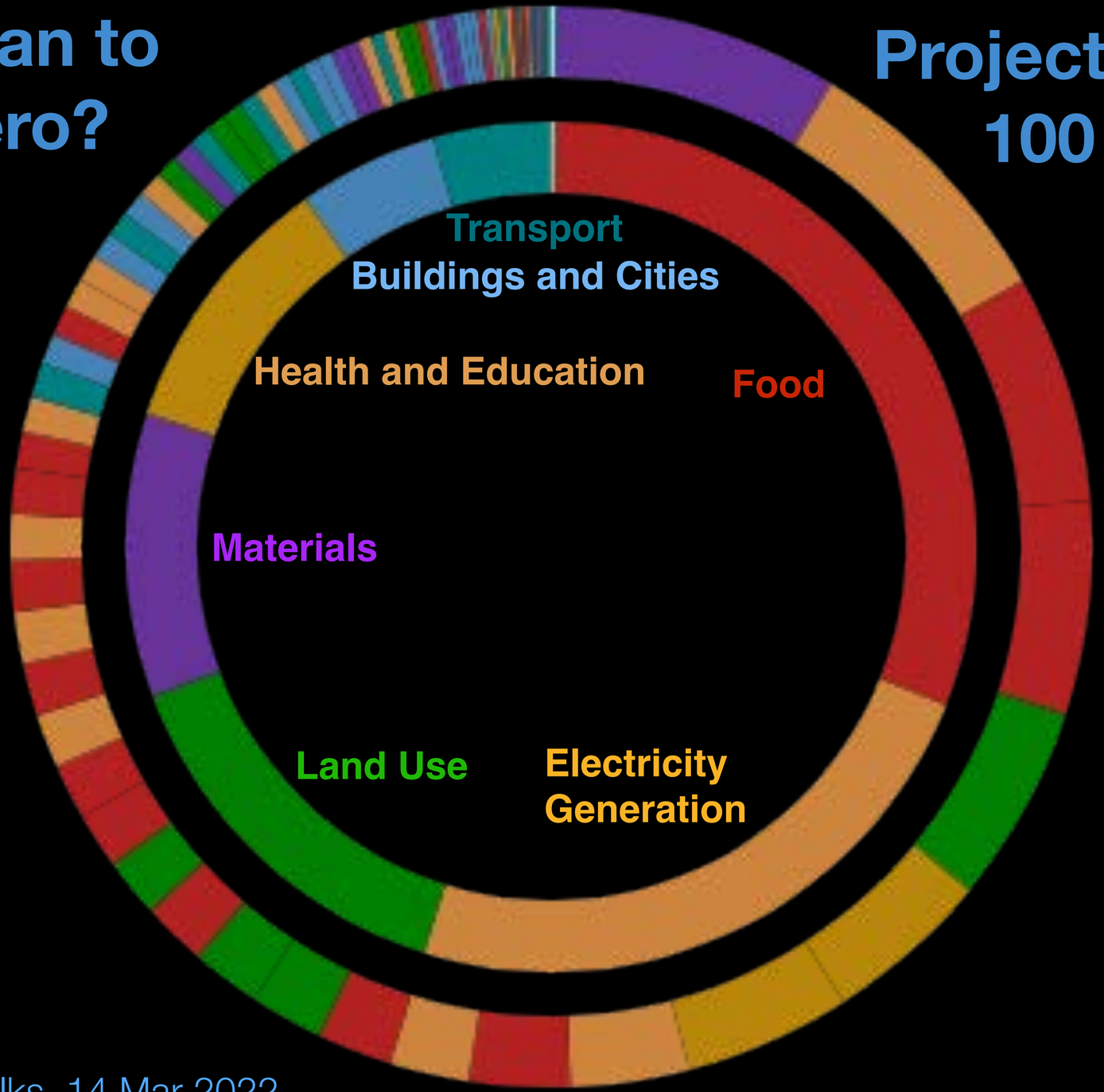
What is the plan to reach NetZero?

Project Drawdown's 100 Solutions



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2020-2050

TOP 20 PLAUSIBLE SCENARIO

RANK	SOLUTION	SECTOR	REDUCED CO2-eq
1	Refrigeration	Materials	89.74 GT
2	Wind Turbines (Onshore)	Electricity	84.60 GT
3	Reduced Food Waste	Food	70.53 GT
4	Plant-Rich Diet	Food	66.11 GT
5	Tropical Forests	Land Use	61.23 GT
6	Educating Girls	Women and Girls	51.48 GT
7	Family Planning	Women and Girls	51.48 GT
8	Solar Farms	Electricity	36.90 GT
9	Silvopasture	Food	31.19 GT
10	Rooftop Solar	Electricity	24.60 GT
11	Regenerative Agriculture	Food	23.15 GT
12	Temperate Forest	Land Use	22.61 GT
13	Peatlands	Land Use	21.57 GT
14	Tropical Staple Tree Crops	Food	20.19 GT
15	Afforestation	Land Use	18.06 GT
16	Conservation Agriculture	Food	17.35 GT
17	Tree Intercropping	Food	17.20 GT
18	Geothermal	Electricity	16.60 GT
19	Managed Grazing	Food	16.34 GT
20	Nuclear	Electricity	16.09 GT

SOLUTION	PLAUSIBLE SCENARIO RANK	PLAUSIBLE SCENARIO GIGATONS REDUCED	DRAWDOWN SCENARIO RANK	DRAWDOWN SCENARIO GIGATONS REDUCED	OPTIMUM SCENARIO RANK	OPTIMUM SCENARIO GIGATONS REDUCED
Refrigeration	1	89.74	2	96.49	3	96.49
Wind Turbines (Onshore)	2	84.60	1	146.50	1	139.31
Reduced Food Waste	3	70.53	4	83.03	4	92.89
Plant-Rich Diet	4	66.11	5	78.65	5	87.86
Tropical Forests	5	61.23	3	89.00	2	105.60
Educating Girls	6	59.60	7	59.60	8	59.60
Family Planning	7	59.60	8	59.60	9	59.60
Solar Farms	8	36.90	6	64.60	7	60.48
Silvopasture	9	31.19	9	47.50	6	63.81
Rooftop Solar	10	24.60	10	43.10	13	40.34
Regenerative Agriculture	11	23.15	14	32.23	15	32.08
Temperate Forest	12	22.61	12	34.70	11	42.62
Peatlands	13	21.57	13	33.51	14	36.59
Tropical Staple Tree Crops	14	20.19	15	31.50	10	46.70
Afforestation	15	18.06	11	41.61	12	41.61
TOTAL (ALL 80 SOLUTIONS)		1,051.01		1,442.27		1,612.89

2020-2050

TOP 20 DRAWDOWN SCENARIO

RANK	SOLUTION	SECTOR	REDUCED CO2-eq
1	Wind Turbines (Onshore)	Electricity	146.47 GT
2	Refrigeration	Materials	96.49 GT
3	Tropical Forests	Land Use	89.00 GT
4	Reduced Food Waste	Food	83.02 GT
5	Plant-Rich Diet	Food	78.65 GT
6	Solar Farms	Electricity	64.57 GT
7	Educating Girls	Women and Girls	51.48 GT
8	Family Planning	Women and Girls	51.48 GT
9	Silvopasture	Food	47.50 GT
10	Rooftop Solar	Electricity	43.06 GT
11	Afforestation	Land Use	41.61 GT
12	Temperate Forest	Land Use	34.70 GT
13	Peatlands	Land Use	33.50 GT
14	Regenerative Agriculture	Food	32.23 GT
15	Tropical Staple Tree Crops	Food	31.50 GT
16	Geothermal	Electricity	28.09 GT
17	Tree Intercropping	Food	26.91 GT
18	Concentrated Solar	Electricity	26.01 GT
19	Electric Vehicles	Transportation	25.26 GT
20	Clean Cookstoves	Food	24.32 GT

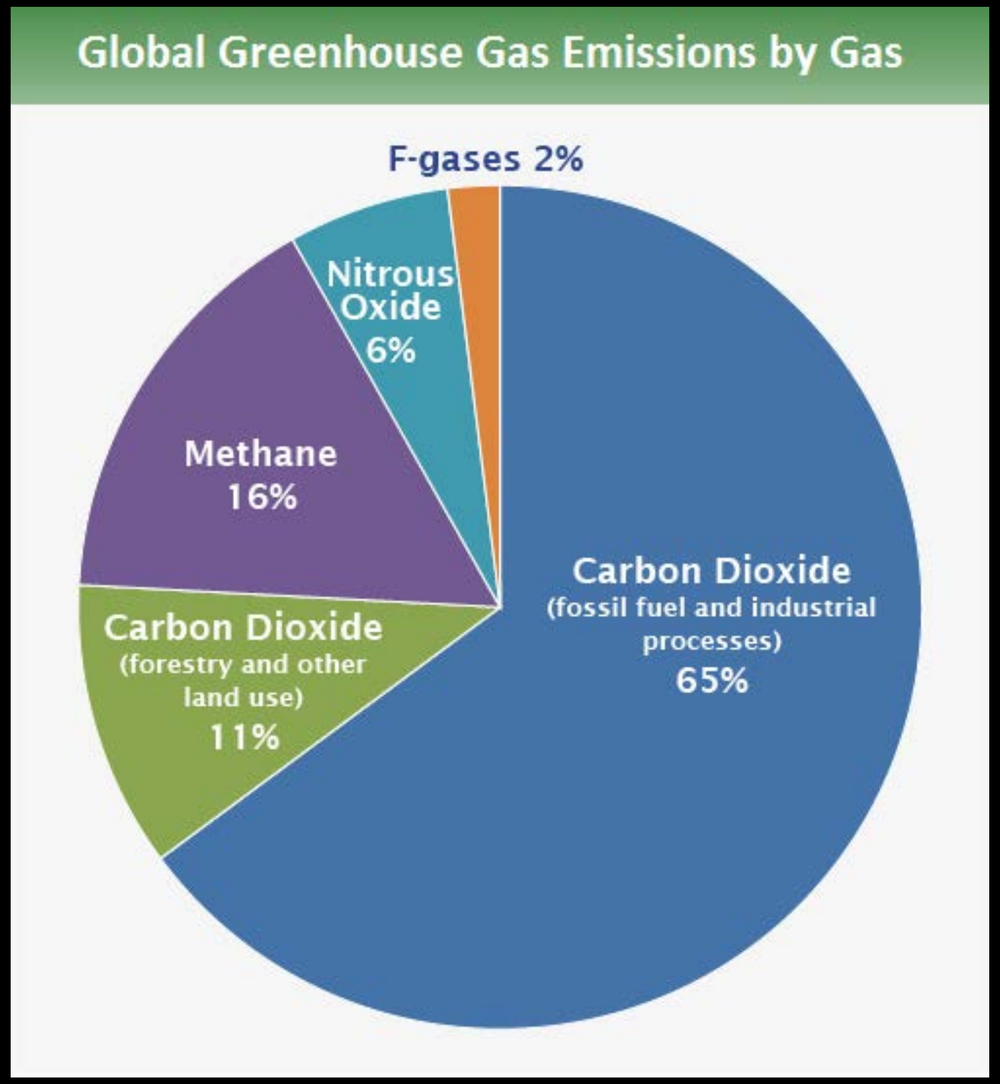
2020-2050

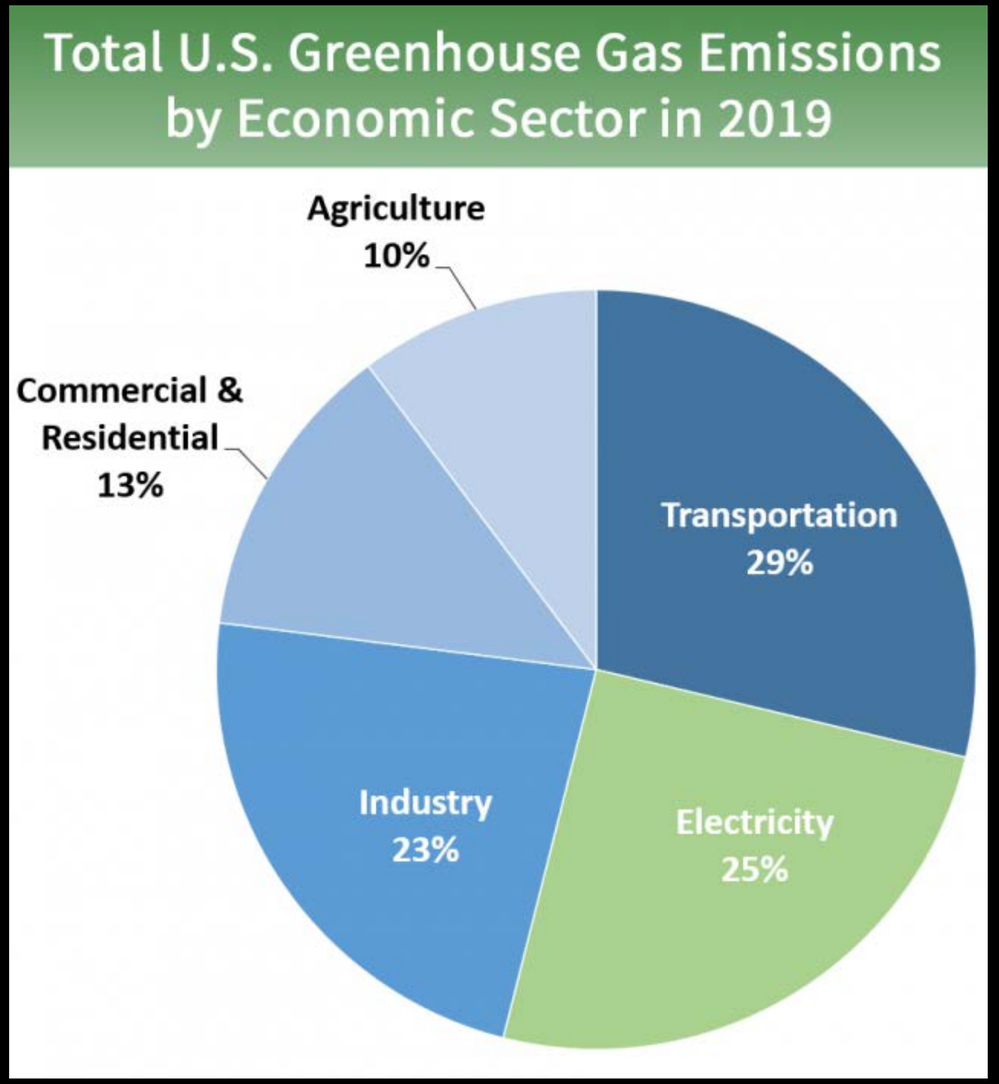
TOP 20

OPTIMUM SCENARIO

RANK	SOLUTION	SECTOR	REDUCED CO2-eq
1	Wind Turbines (Onshore)	Electricity	139.31 GT
2	Tropical Forests	Land Use	105.61 GT
3	Refrigeration	Materials	96.49 GT
4	Reduced Food Waste	Food	93.72 GT
5	Plant-Rich Diet	Food	87.03 GT
6	Silvopasture	Food	63.81 GT
7	Solar Farms	Electricity	60.48 GT
8	Electric Vehicles	Transportation	52.38 GT
9	Educating Girls	Women and Girls	51.48 GT
10	Family Planning	Women and Girls	51.48 GT
11	Tropical Staple Tree Crops	Food	46.70 GT
12	Temperate Forest	Land Use	42.63 GT
13	Afforestation	Land Use	41.61 GT
14	Rooftop Solar	Electricity	40.34 GT
15	Tree Intercropping	Food	36.62 GT
16	Peatlands	Land Use	36.59 GT
17	Regenerative Agriculture	Food	32.07 GT
18	Farmland Restoration	Food	30.49 GT
19	Bamboo	Land Use	28.63 GT
20	Managed Grazing	Food	27.65 GT

What are the sources?





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