Exploring climate change drivers and solutions in multiple sectors

17th March 2025,
Fundamentals on Environment and Sustainability, NOVA SBE

João Pedro Gouveia, PhD, jplg@fct.unl.pt

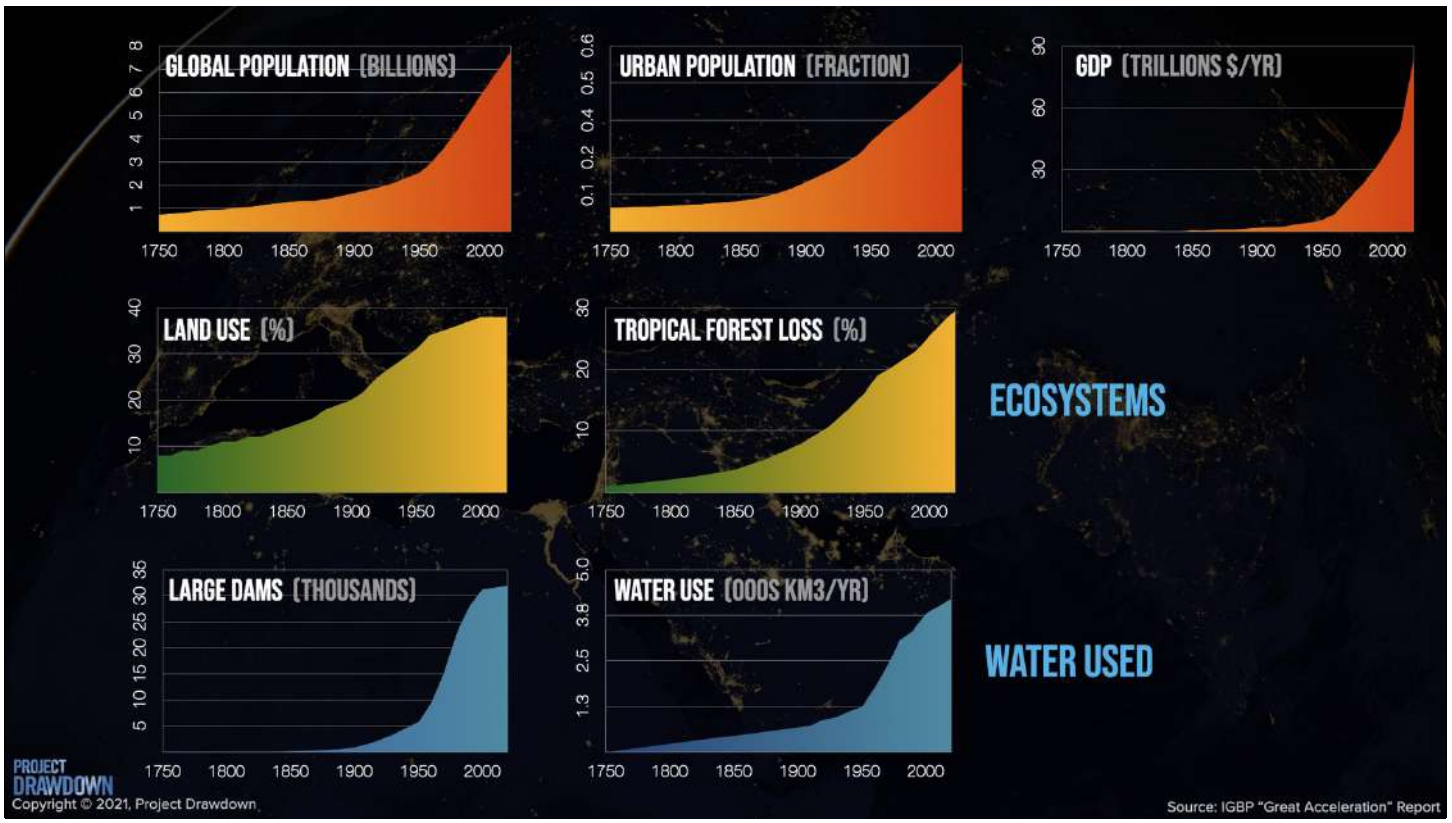
Principal Researcher, CENSE & CHANGE, NOVA School of Science and Technology, NOVA University of Lisbon (NOVA – FCT)

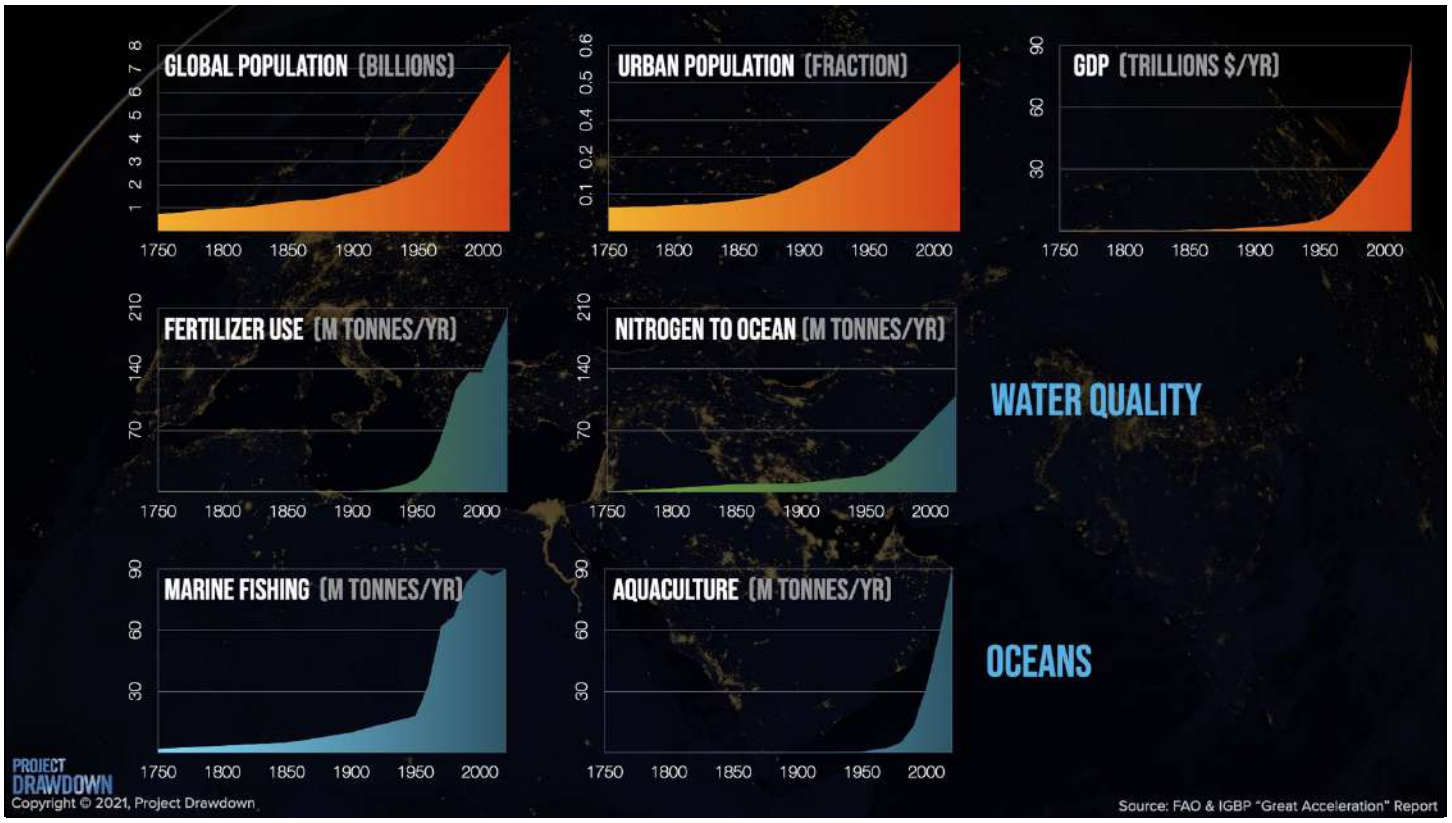
João Pedro Gouveia

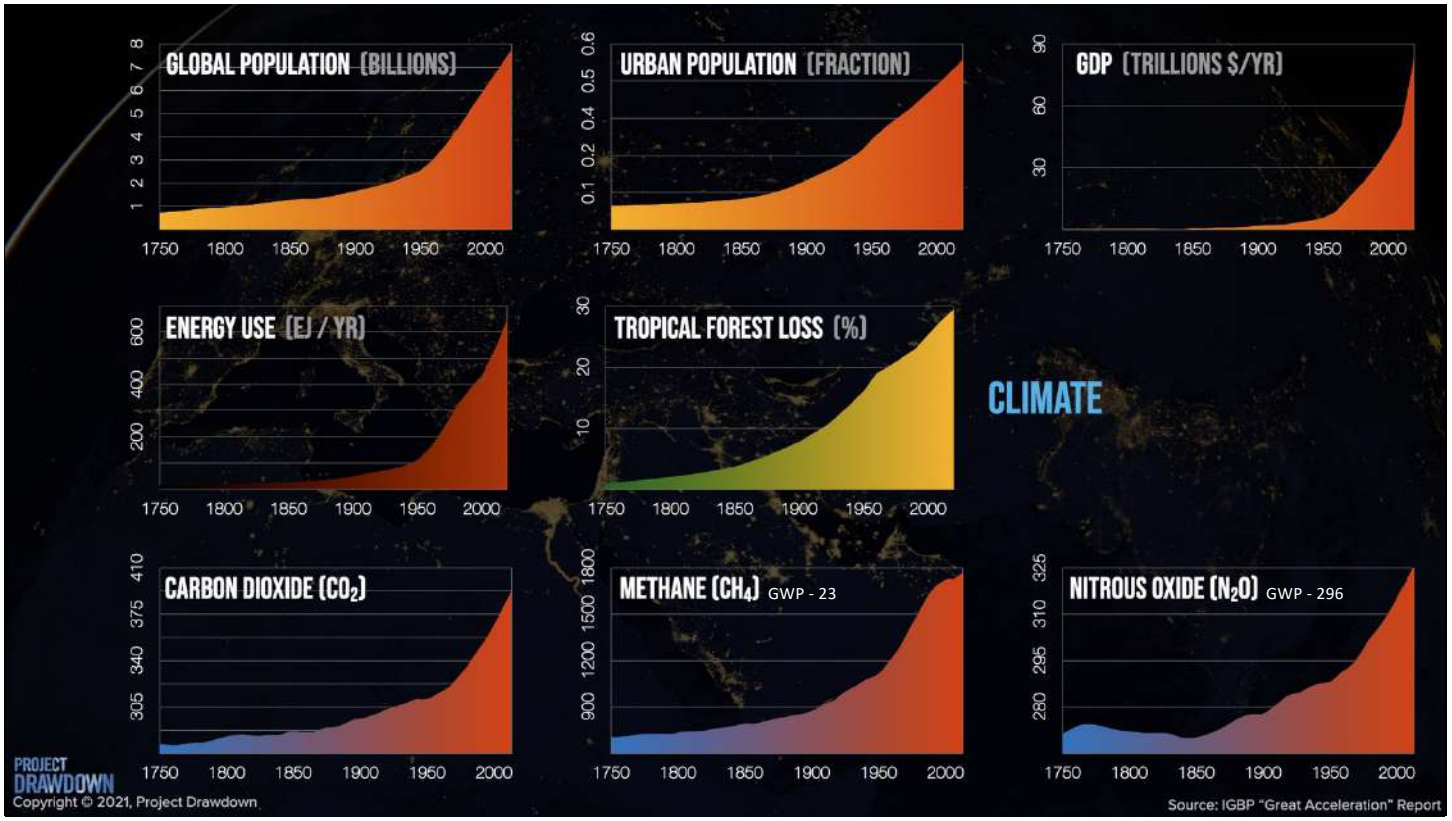
- Father of 3 girls 
- MSc. in Environmental Engineer (2008) [FCT-NOVA, Portugal]
- PhD in Climate Change and Sustainable Development Policies (2017) [FCT-NOVA, Portugal]
- Lab Leader – **Firefly Energy lab** (Buildings Energy Efficiency, Energy Poverty and Sustainable Energy Transitions Research)
- Invited Lecturer at **FCT-NOVA**
- Integrated Member and Researcher in Energy and Climate Change (2008-…) [CENSE, FCT-NOVA, Portugal]
- Coordinator of the **CHANGE Global Change and Sustainability Institute** Thematic Line on Circular and carbon-neutral economy.
- Scientific Coordination of the **EU Energy Poverty Advisory HUB** (2021-…) [EPAH, Brussels]
- Co-founder of **RegenIntel** **(USA)**
- Senior Researcher Energy Systems (2016-2020) [Project Drawdown, USA]
- Founder and Board Member **Drawdown Europe Research Association** (2019-2022) [DERA, The Netherlands]
- Founder and Board Member **Portuguese Association for Energy Economics** (2015-…) [APEEN, Portugal)

What you need to know/be able to, after this class?

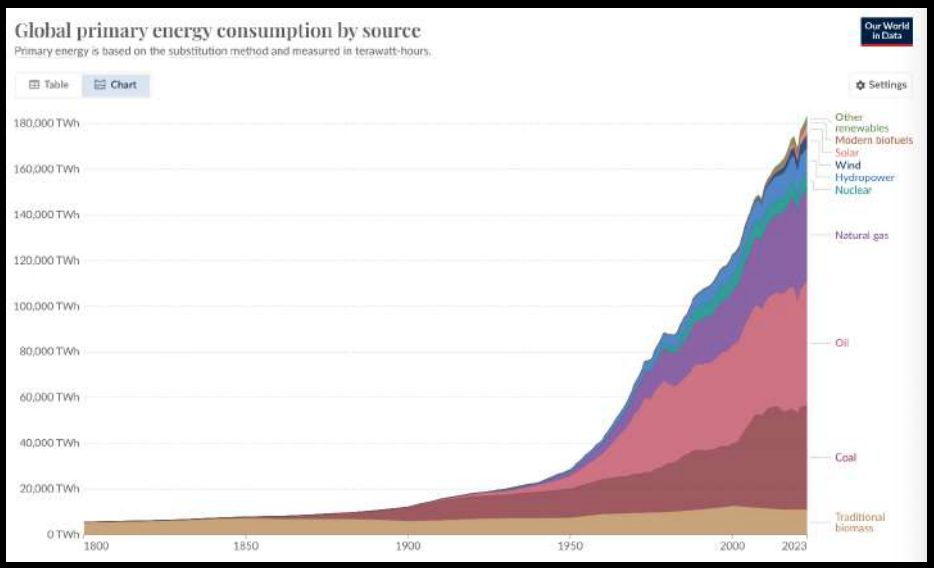
- Describe the greenhouse effect and why it is being exacerbated.
- What are the main greenhouse gas emissions, and what is their role in global warming?
- Who have been the main emitters, and what are the main causes?
- Tell stories about evidence of climate change.
- Know the concept of Drawdown.
- Identify and assess the relevance of multiple sectors' solutions.


GLOBAL POPULATION (BILLIONS)
URBAN POPULATION (FRACTION)
GDP (TRILLIONS $/YR)
LAND USE (%)
TROPICAL FOREST LOSS (%)
ECOSYSTEMS
LARGE DAMS (THOUSANDS)
WATER USE (000S KM3/YR)
WATER USED
1750 1800 1850 1900 1950 2000
PROJECT DRAWDOWN
Copyright © 2021, Project Drawdown
Source: IGBP "Great Acceleration" Report


GLOBAL POPULATION (BILLIONS)
URBAN POPULATION (FRACTION)
GDP (TRILLIONS $/YR)
FERTILIZER USE (M TONNES/YR)
NITROGEN TO OCEAN (M TONNES/YR)
WATER QUALITY
MARINE FISHING (M TONNES/YR)
AQUACULTURE (M TONNES/YR)
OCEANS
1750 1800 1850 1900 1950 2000
PROJECT DRAWDOWN
Copyright © 2021, Project Drawdown
Source: FAO & IGBP "Great Acceleration" Report



Energy consumption since pre-industrial era



2023:

Fossil Fuels: 77%

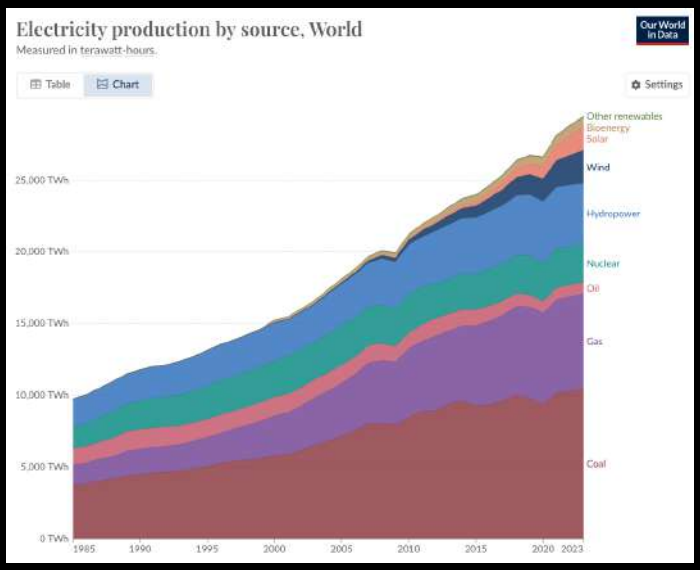
Renewables: 20%

Renewables without traditional biomass and Hydro: 8%

Nuclear: 4%

Source: OurWolrdinData.org (2024)

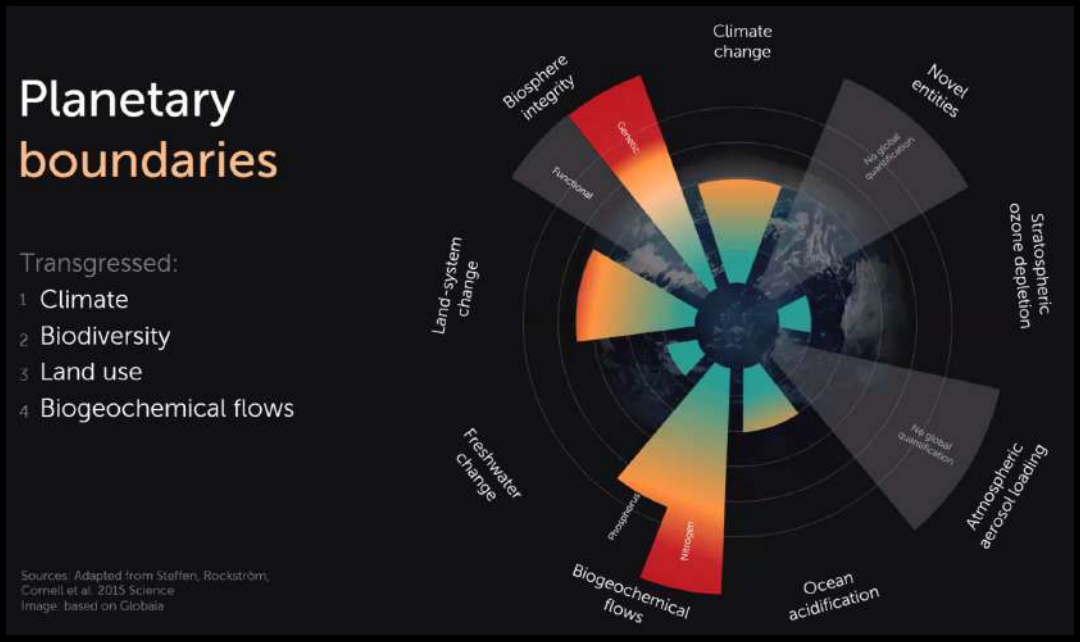
Electricity Production by Source



- Coal (35.5%), followed by gas (22,5%), is the largest source of electricity production.
- Of the low-carbon sources, hydropower (14%) and nuclear (9%) make the largest contribution;
- Wind (7.8%) and solar (5.5%) are growing quickly.

©João Pedro Gouveia, FCT NOVA, 2025

OurWorldinData.org (2024)



Humanity has exceeded a planetary boundary related to environmental pollutants and other “novel entities” including plastics.

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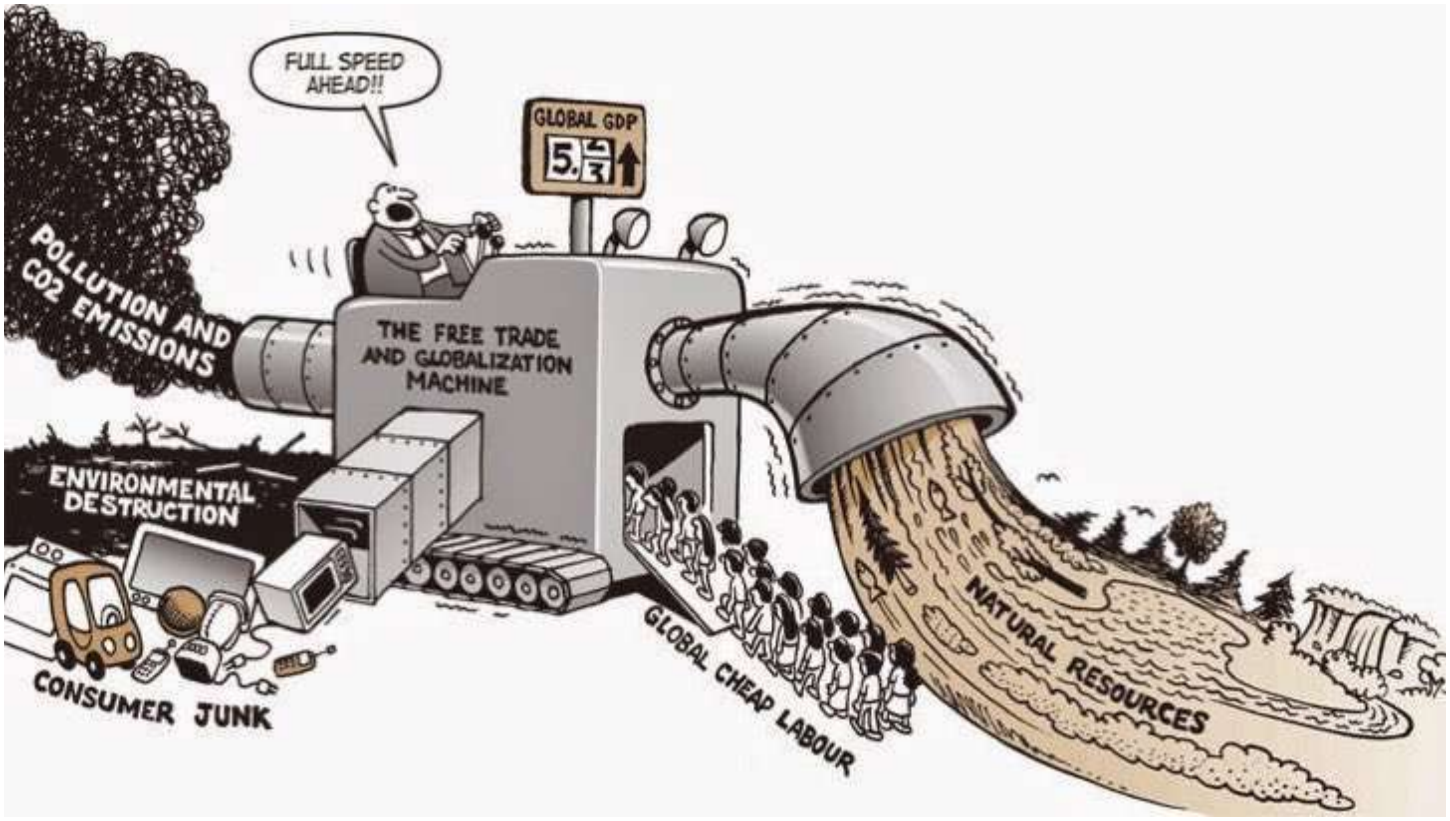

FULL SPEED AHEAD!!
GLOBAL GDP
5.3
POLLUTION AND CO2 EMISSIONS
THE FREE TRADE AND GLOBALIZATION MACHINE
ENVIRONMENTAL DESTRUCTION
CONSUMER JUNK
GLOBAL CHEAP LABOUR
NATURAL RESOURCES


DISRUPTING ENTIRE PLANET
IMAGE: NASA

HARM THE MOST VULNERABLE

BURDEN FUTURE GENERATIONS

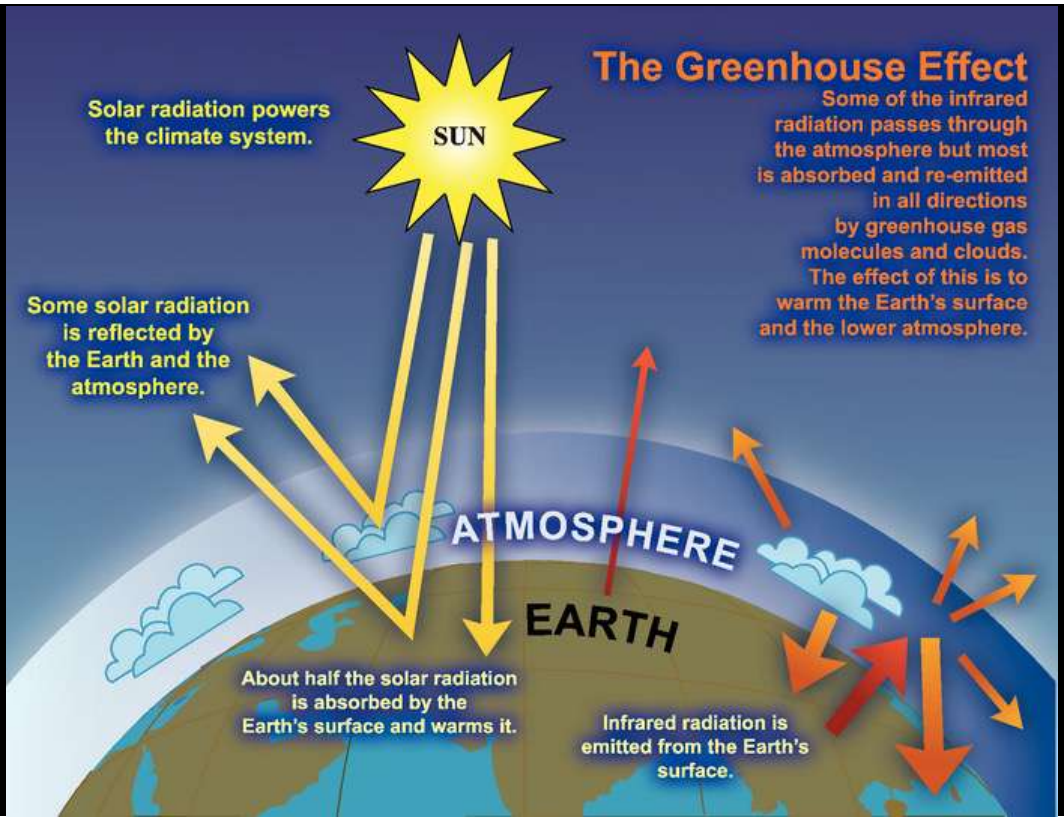
Timelapse in Google Earth

Baban Rafi deforestation, Niger
January 12, 1976 - February 2, 2007

IMAGES of CHANGE

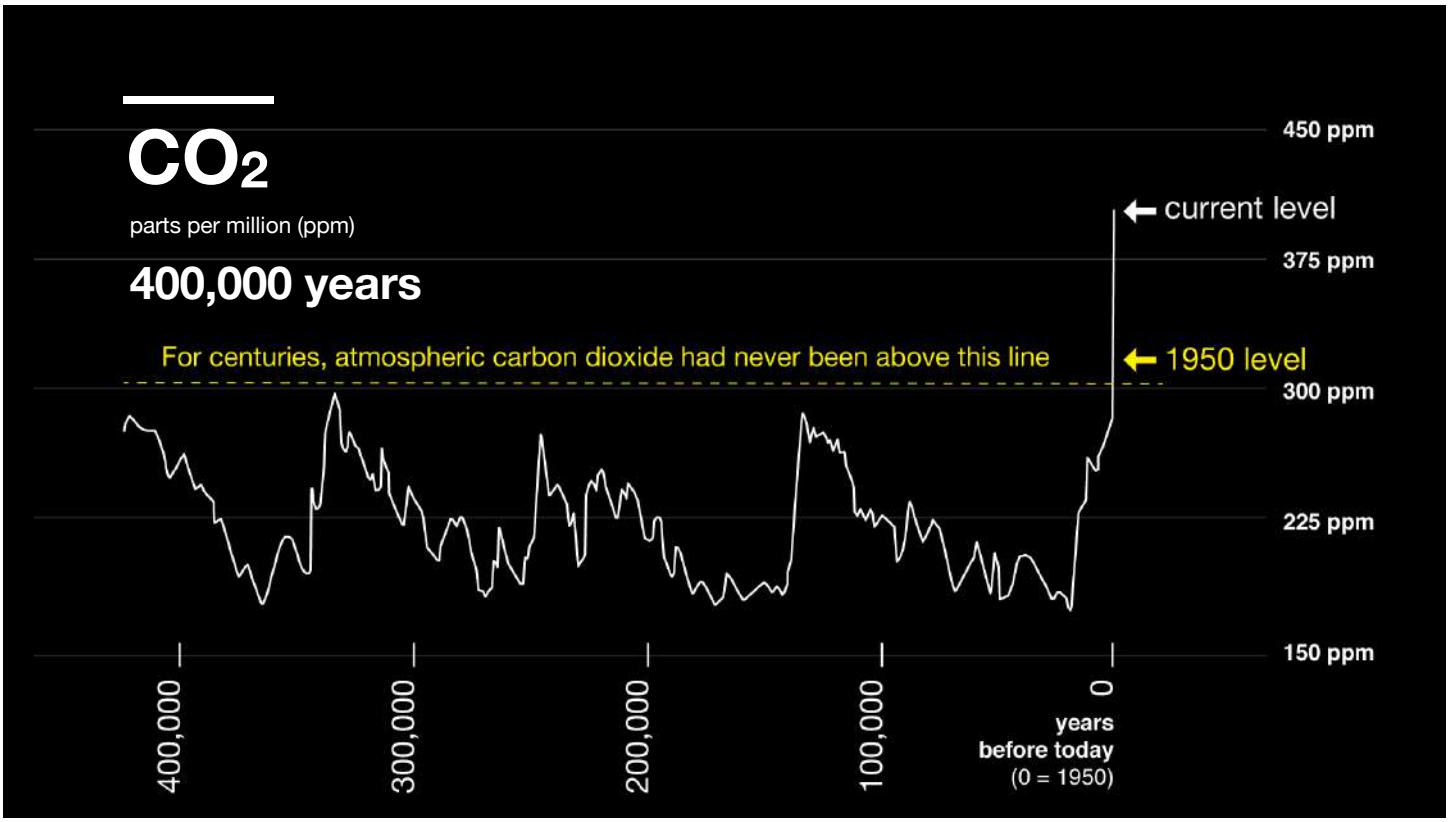

WATER RESOURCES ARE COLLAPSING ACROSS THE GLOBE
Shrinking Aral Sea, central Asia
August 25, 2000 - August 19, 2014
IMAGES of CHANGE

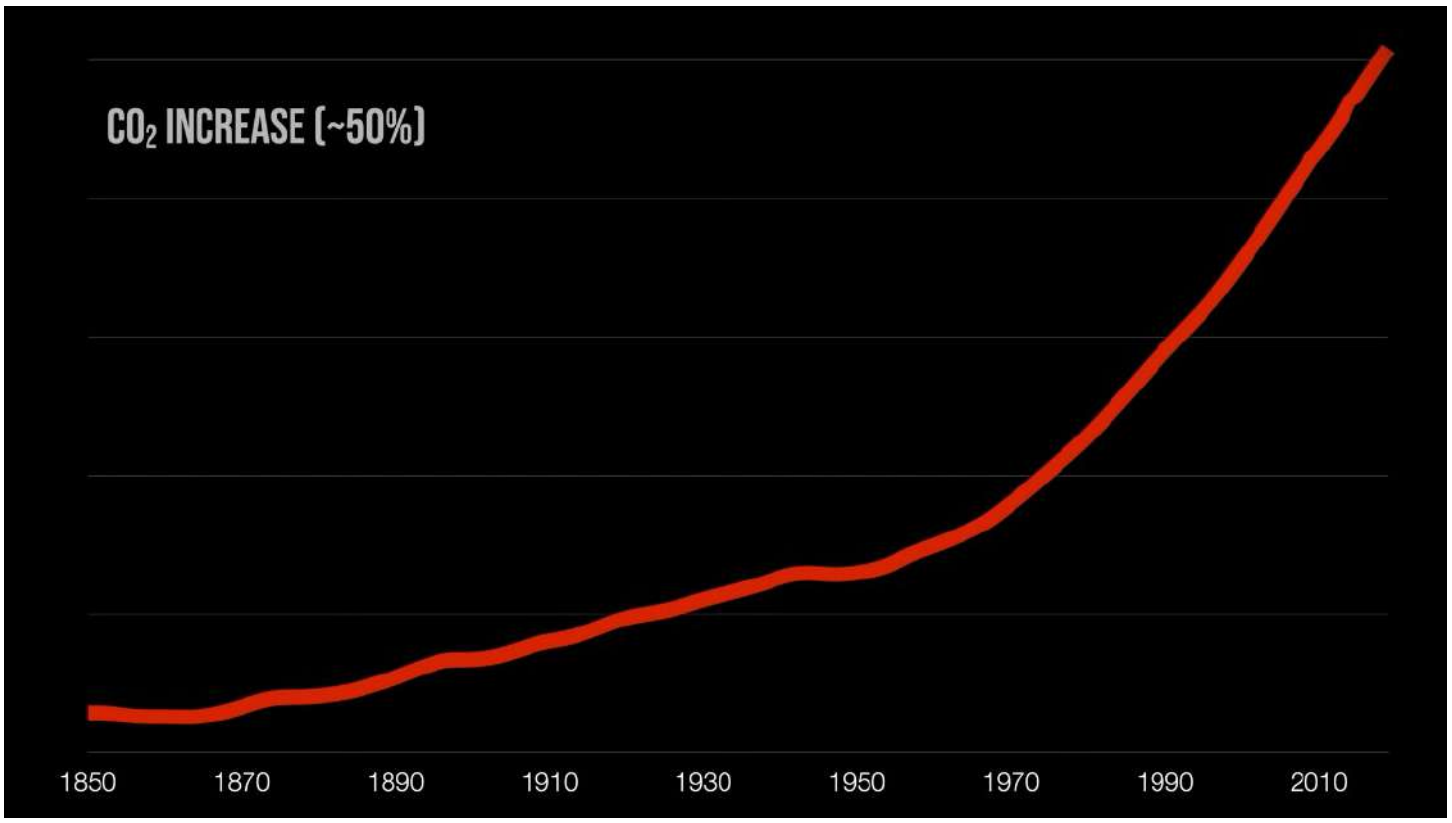

CHANGING EARTH'S CLIMATE

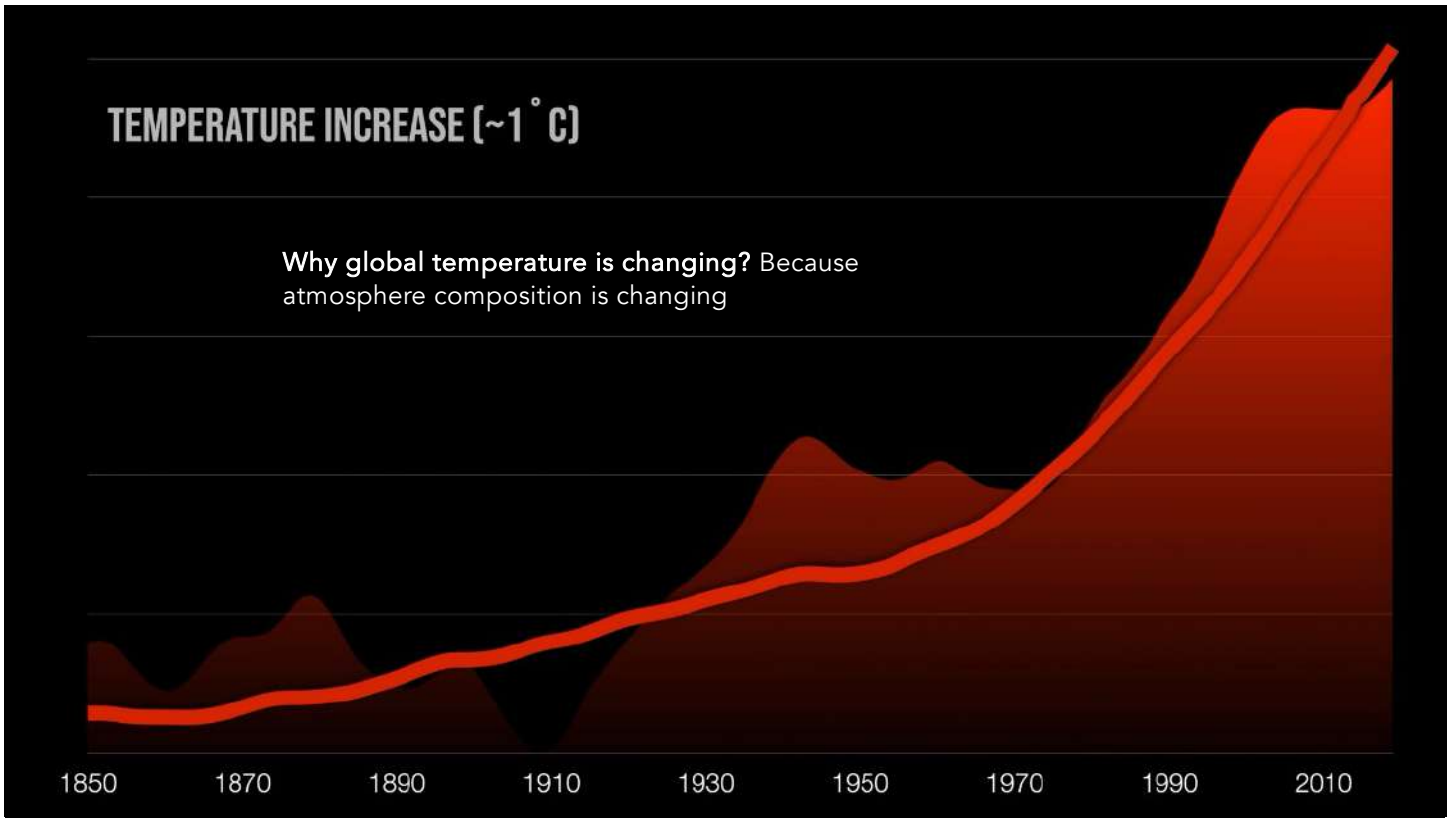


That's what keeps our Earth a warm and cosy 15°C, on average.

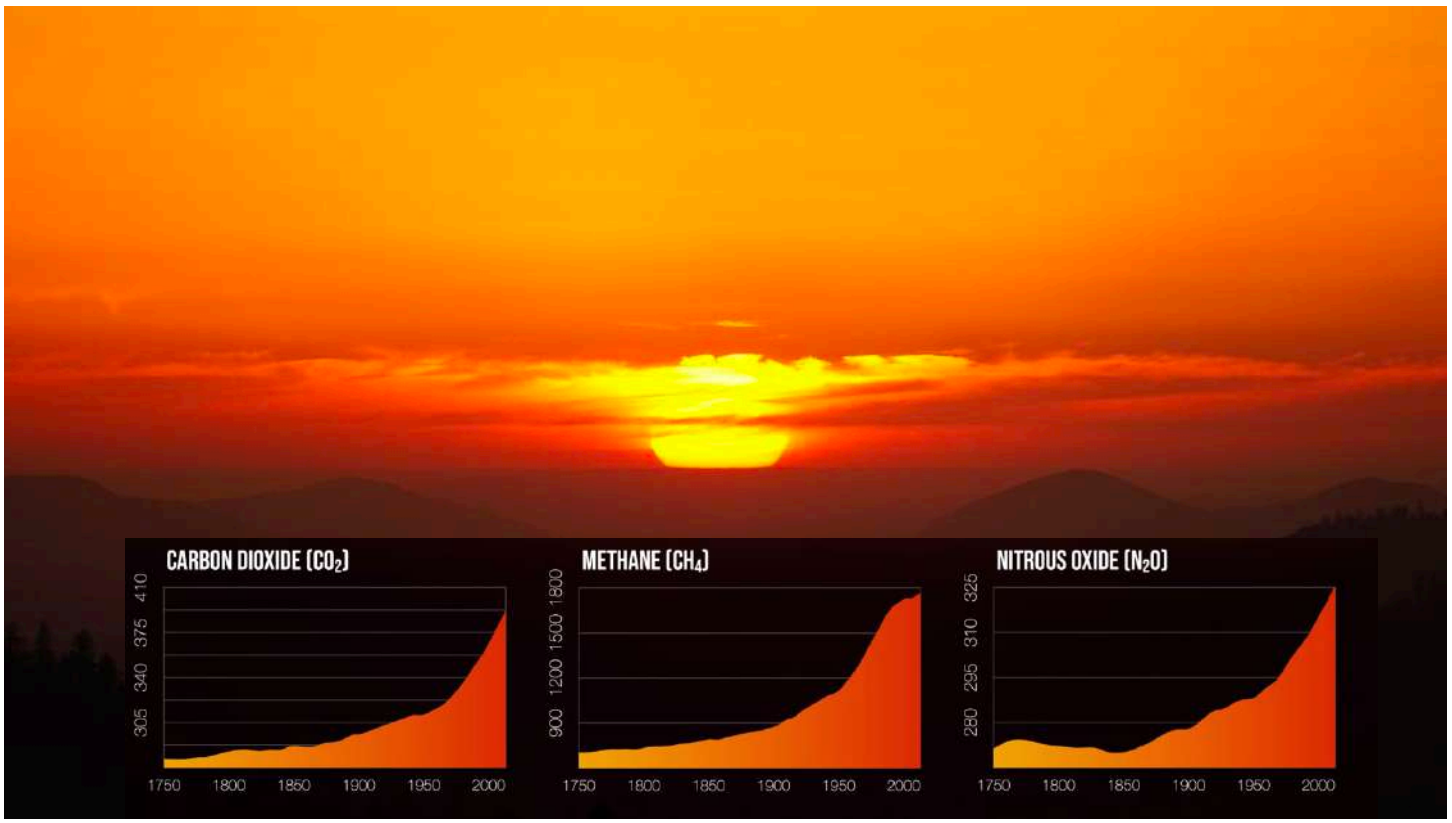
CO_2 plays a crucial role in maintaining the stability of Earth's atmosphere. If CO_2 was removed, the terrestrial greenhouse effect would collapse, and Earth's surface temperature would drop significantly by approximately 33°C (59°F).

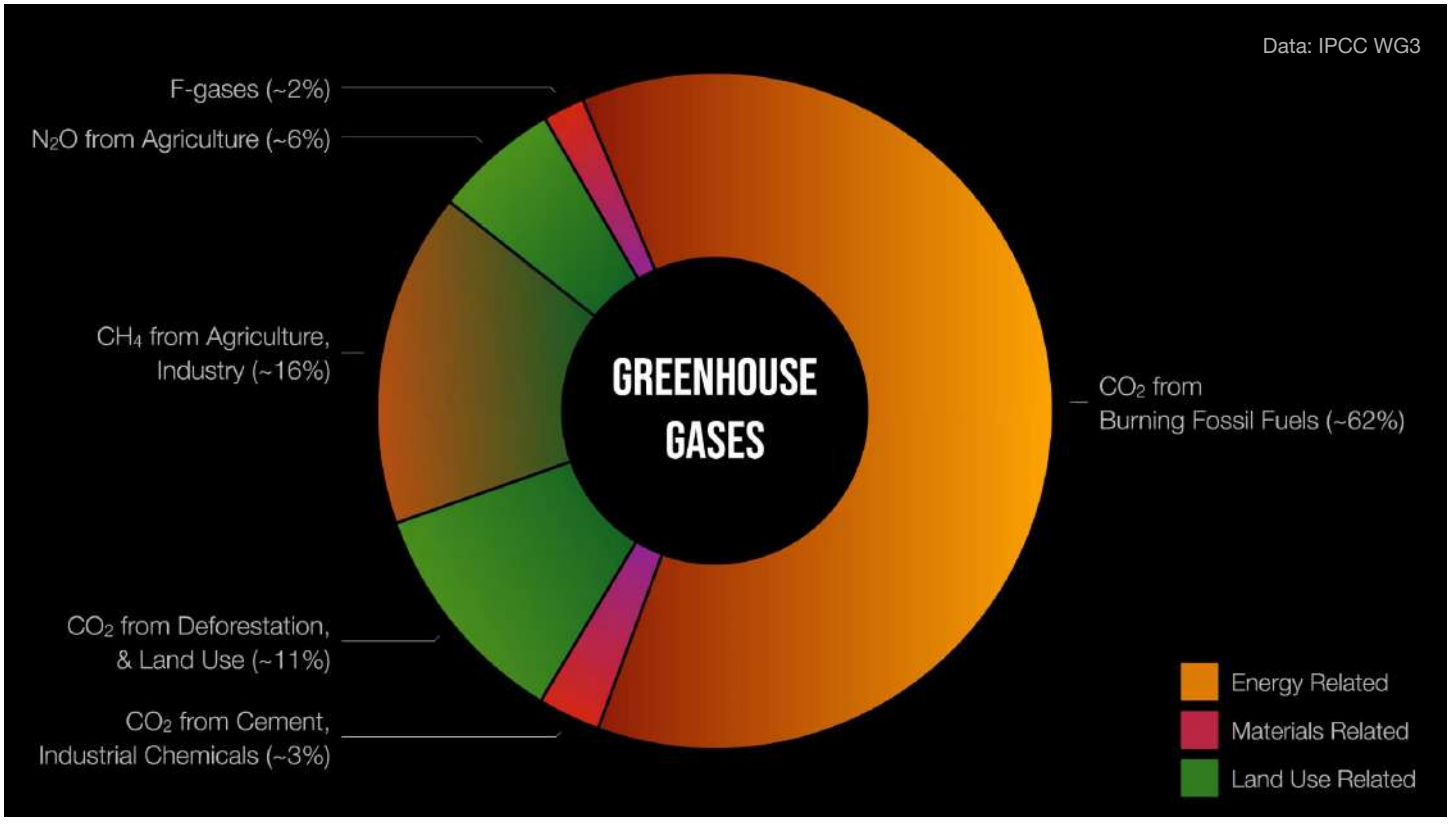


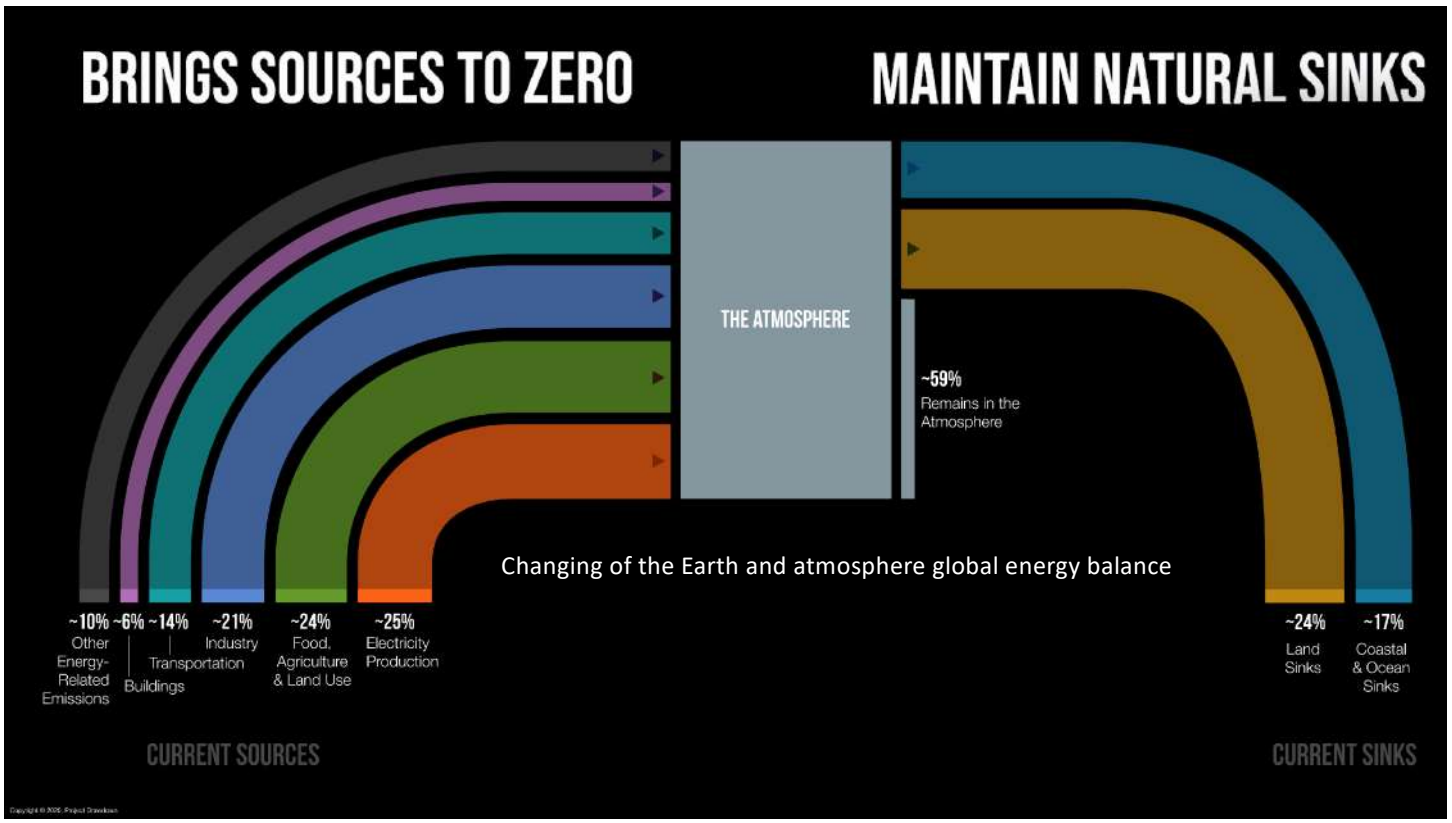

CO_2 INCREASE (~50%)
1850
1870
1890
1910
1930
1950
1970
1990
2010


TEMPERATURE INCREASE (~1 ° C)
Why global temperature is changing? Because atmosphere composition is changing
1850
1870
1890
1910
1930
1950
1970
1990
2010

THE PROBLEM


CARBON DIOXIDE (CO_2)
305 340 375 410
1750 1800 1850 1900 1950 2000
METHANE (CH_4)
900 1200 1500 1800
1750 1800 1850 1900 1950 2000
NITROUS OXIDE (N_2O)
280 295 310 325
1750 1800 1850 1900 1950 2000

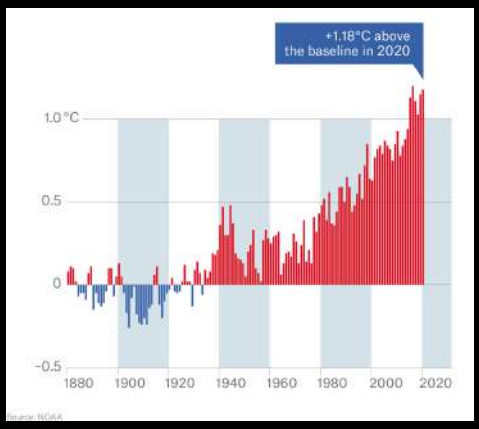

Data: IPCC WG3
F-gases (~2%)
N_2O from Agriculture (~6%)
CH_4 from Agriculture, Industry (~16%)
CO_2 from Deforestation, & Land Use (~11%)
CO_2 from Cement, Industrial Chemicals (~3%)
GREENHOUSE GASES
CO_2 from Burning Fossil Fuels (~62%)
Energy Related
Materials Related
Land Use Related



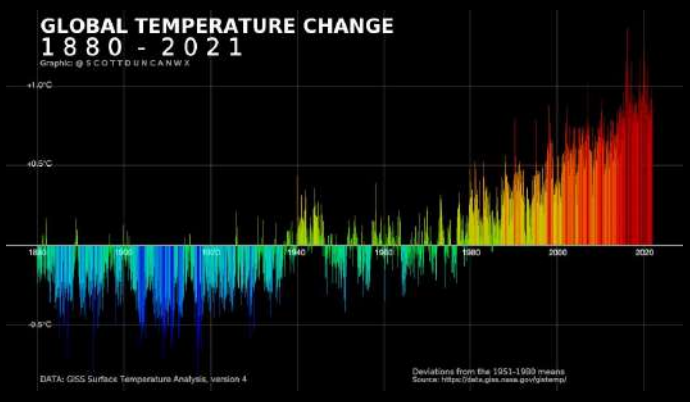
Changing of the Earth and atmosphere global energy balance

Climate Change

Deviation in global mean temperature from the 1880–1900 average

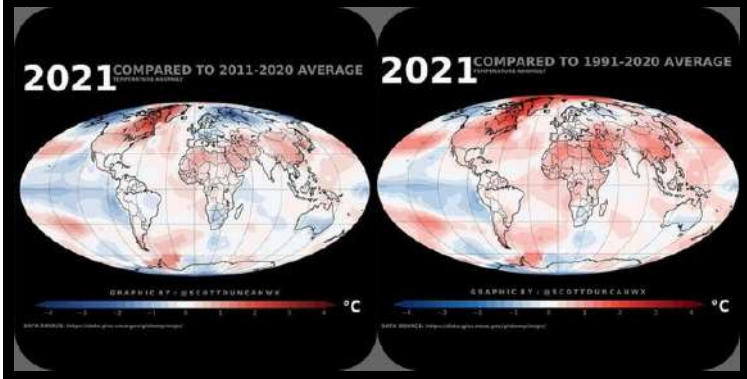


Deviation in global mean temperature from the 1951–1980 average

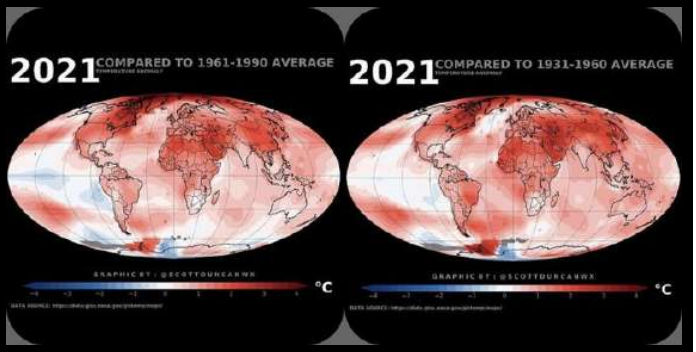


All 19 years since 2002 rank among the 20 warmest since measurements began

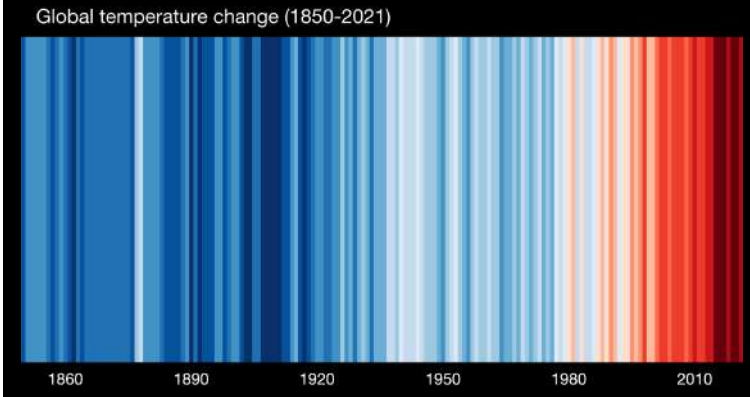
Climate Change



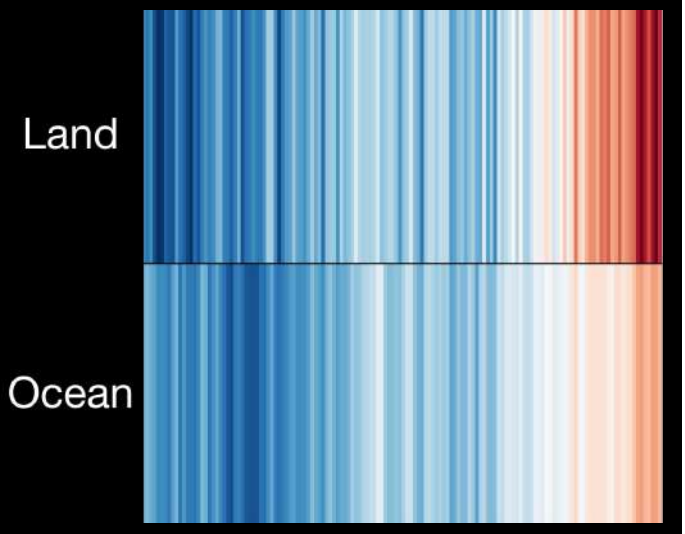
How does 2021 temperature compare to the average from various decades over the last century?



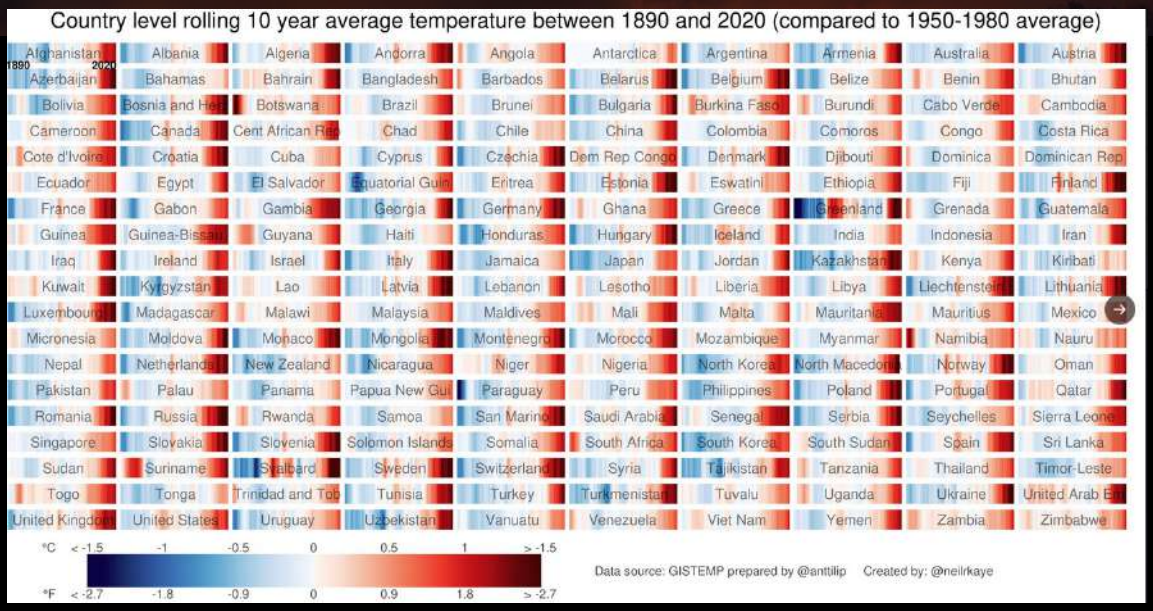
Climate Change



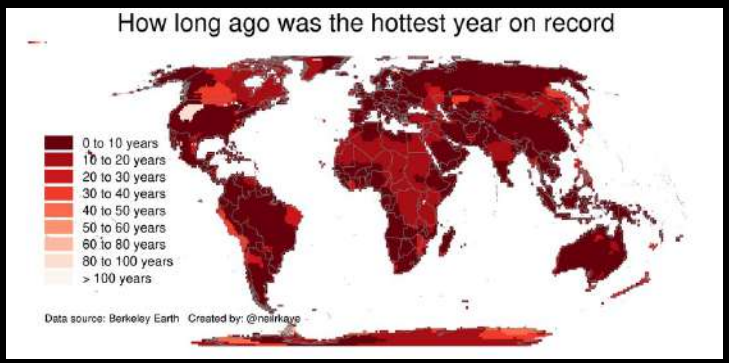
https://showyourstripes.info/s/globe

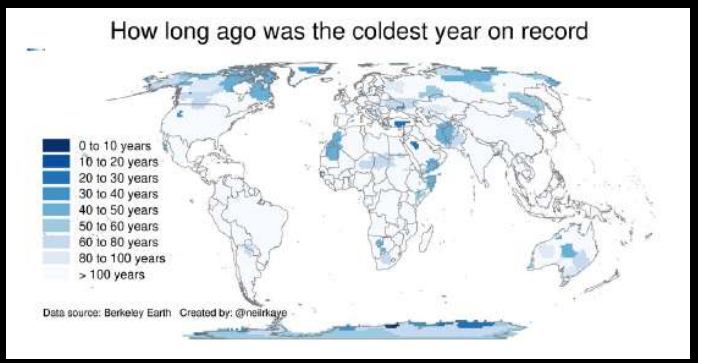


Climate Change



Climate Change





Climate Change Impacts

It's a striking statement because it names what so often goes unspoken – the fact of **climate suffering**.

- That includes natural disasters such as the **wildfires California**, Portugal or Greece **have** experienced in recent years.
- **Drought in Australia, or floods across Somalia, Cameroon and Nigeria.**

Climate Change Impacts

Extreme heat forces school closures and rekindles wildfire on the Canary Islands

By Rebecca Ann Hughes with AFP

Published on 12/10/2023 - 11:48

Climate crisis

Global heating made Greece and Libya floods more likely, study says

Report says climate change made rainfall heavier but human factors turned extreme weather into humanitarian disaster

Ajit Niranjan *Europe environment correspondent*

Tue 19 Sep 2023 15.00 CEST

A destroyed building in the Libyan city of Derna after deadly flash floods. The volume of rain that fell was 'far outside that of previously recorded events'. Photograph: Karim Sahib/AFP/Getty

Climate Change Impacts

- Displacement or **loss of ancestral homelands** – as a low-lying coral atoll nation in tropical pacific islands (e.g. Marshall Islands declared a national climate crisis back in 2019.
- **New diseases**. Studies suggests that climate change will widen the area exposed to the Ebola virus.

©João Pedro Gouveia, FCT NOVA, 2025

Climate Change Impacts

- It could be **loss of cultural traditions**, such as the growing risks to the Hajj (pilgrimage to Mecca) .
- Animal suffering, such as the **elephants starving** to death in drought–struck national parks in Zimbabwe .

Climate Change Impacts

- Research demonstrates that the extreme weather events associated with a changing climate can impair mental health, in particular leading to **increases in depression and post–traumatic stress disorder**
- More gradual changes in climatic conditions, such as rising temperatures and reduced air quality, are also **harmful to mental health**
- There is increasing evidence that a significant proportion of people might be experiencing a harmful level of anxiety associated with their perception of climate change and governments inability to act and personal limitation of impacts .

https://pubmed.ncbi.nlm.nih.gov/32210846/

https://pubmed.ncbi.nlm.nih.gov/33389625/

Hot Poles

30°C above normal in the Arctic (20th March 2022).

40°C above normal in the Antarctic today (20th March 2022).

https://www.theguardian.com/environment/2022/mar/21/extremes-of-40c-above-normal-whats-causing-extraordinary-heating-in-polar-regions

Nine Climate Tipping Points now Active"

This is what we now start seeing, already at 1.1°C global warming. **Domino effects have also been proposed.**

1. Arctic Sea Ice (Reduction in area)
2. Greenland Ice Sheet (Ice loss accelerating)
3. Boreal Forests (Fires and pests changing)
4. Permafrost (thawing)
5. Atlantic Meridional Overturning Circulation (In slowdown since 1950's)
6. Amazon Rainforest (Frequent Droughts)
7. Warm Water Corals (Large Scale die-offs)
8. West Antarctic Ice Sheet (Ice Loss accelerating)
9. Parts of East Antarctica (Ice Loss accelerating)

The evidence from tipping points alone suggests that we are in a state of planetary emergency: both the risk and urgency of the situation are acute

https://www.nature.com/articles/d41586-019-03595-0

Climate Change – Financial Impacts

Weather-related disasters increase over past 50 years, causing more damage but fewer deaths

A disaster related to a weather, climate or water hazard occurred every day on average over the past 50 years – killing 115 people and causing US$ 202 million in losses daily,

Economic losses have increased sevenfold from the 1970s to the 2010s.

- 2010–2019 (US$ 383 million per day on average over the decade)
- 1970–1979 (US$ 49 million).

The Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019) WMO, 2021

Table 1. Top 10 disasters ranked according to reported (a) deaths and (b) economic losses (1970–2019)[1]

(a)	Disaster type	Year	Country	Deaths
1	Drought	1983	Ethiopia	300 000
2	Storm (Bhola)	1970	Bangladesh	300 000
3	Drought	1983	Sudan	150 000
4	Storm (Gorky)	1991	Bangladesh	138 866
5	Storm (Nargis)	2008	Myanmar	138 366
6	Drought	1973	Ethiopia	100 000
7	Drought	1981	Mozambique	100 000
8	Extreme temperature	2010	Russian Federation	55 736
9	Flood	1999	Bolivarian Republic of Venezuela	30 000
10	Flood	1974	Bangladesh	28 700

(b)	Disaster type	Year	Country	Economic losses (in US$ billion)
1	Storm (Katrina)	2005	United States	163.61
2	Storm (Harvey)	2017	United States	95.94
3	Storm (Maria)	2017	United States	69.39
4	Storm (Irma)	2017	United States	58.16
5	Storm (Sandy)	2012	United States	54.47
6	Storm (Andrew)	1992	United States	48.27
7	Flood	1998	China	47.02
8	Flood	2011	Thailand	45.46
9	Storm (Ike)	2008	United States	35.63
10	Flood	1995	Democratic People's Republic of Korea	25.17

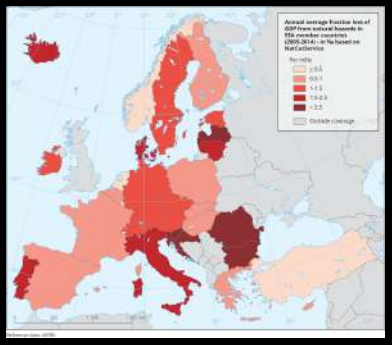
Climate Change – Financial Impacts

Extreme weather has cost Europe about €500bn over 40 years

European Environment Agency data shows worst-hit countries to be Germany, France and Italy

Between 1980 and 2020, **total economic losses from weather- and climate-related events amounted to EUR 450-520 billion** (in 2020 euros) in the 32 EEA member countries (EEA-32).

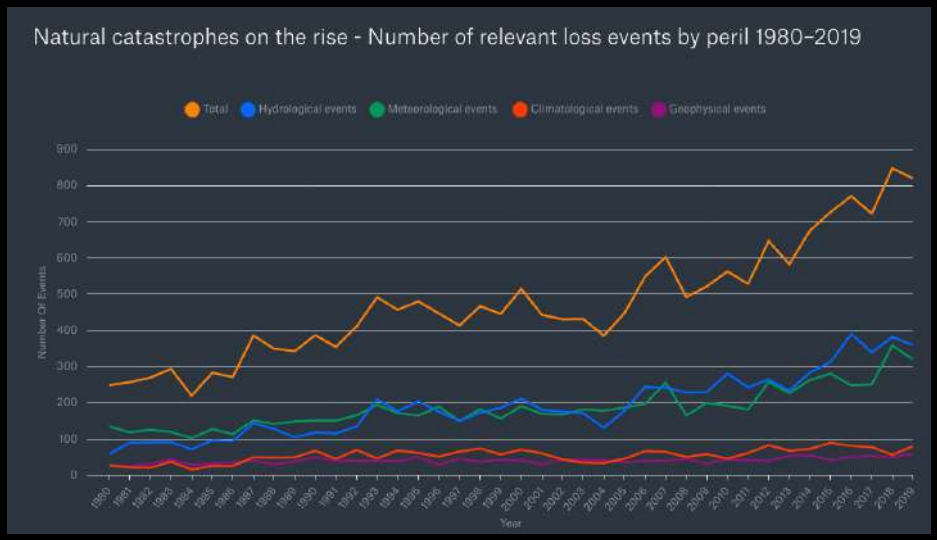
Based on data from two separate sources (NatCatSERVICE and CATDAT), **fatalities during the same period amounted to between 85,000 and 145,000.**



https://www.eea.europa.eu/publications/economic-losses-and-fatalities-from/economic-losses-and-fatalities-from

Climate Change – Financial Impacts

Earthquakes, storms, floods and droughts — the number of recorded loss events resulting from natural disasters has been increasing



How do we get the news about global warming?

Global warming could wipe out millions in world's major cities with catastrophic 'THREE METRE sea level rise'

18:44, 18 MAY 2016 | **UPDATED** 19:22, 18 MAY 2016 | **BY** JESSICA HAWORTH , STEPHEN BEECH

London, New York and Hong Kong are among the cities which could be underwater if global warming continues

★ Recommended In UK News

DANGEROUS DOGS
Blyth dog attack: 'Hero' schoolgirl saves seven-year-old from being mauled to death by crazed Staffie

INQUESTS
Wife 'smashed husband's head with frog ornament and kept him mummified in layers of sheeting for 18 years'

INCREDIBLE ESCAPES
Dashcam captures shocking moment huge bridge collapses and falls 60ft next to busy motorway

ISIS
ISIS murder 25 'spies' by tying them together and

ENERGY

THE DAILY CALLER NEWS FOUNDATION

Noah's ark during a rain and lightning storm. (Credit: Amanda Carden/Shutterstock)

'Potential Apocalypse': NYT Warns Of Global Warming Floods Of Biblical Proportions

MICHAEL BASTASCH

7:08 PM 05/20/2017

The New York Times has taken warnings about global warming to a whole new level, publishing a three-part series suggesting a "potential apocalypse" from melting ice sheets if humans keep pumping carbon dioxide into the atmosphere.

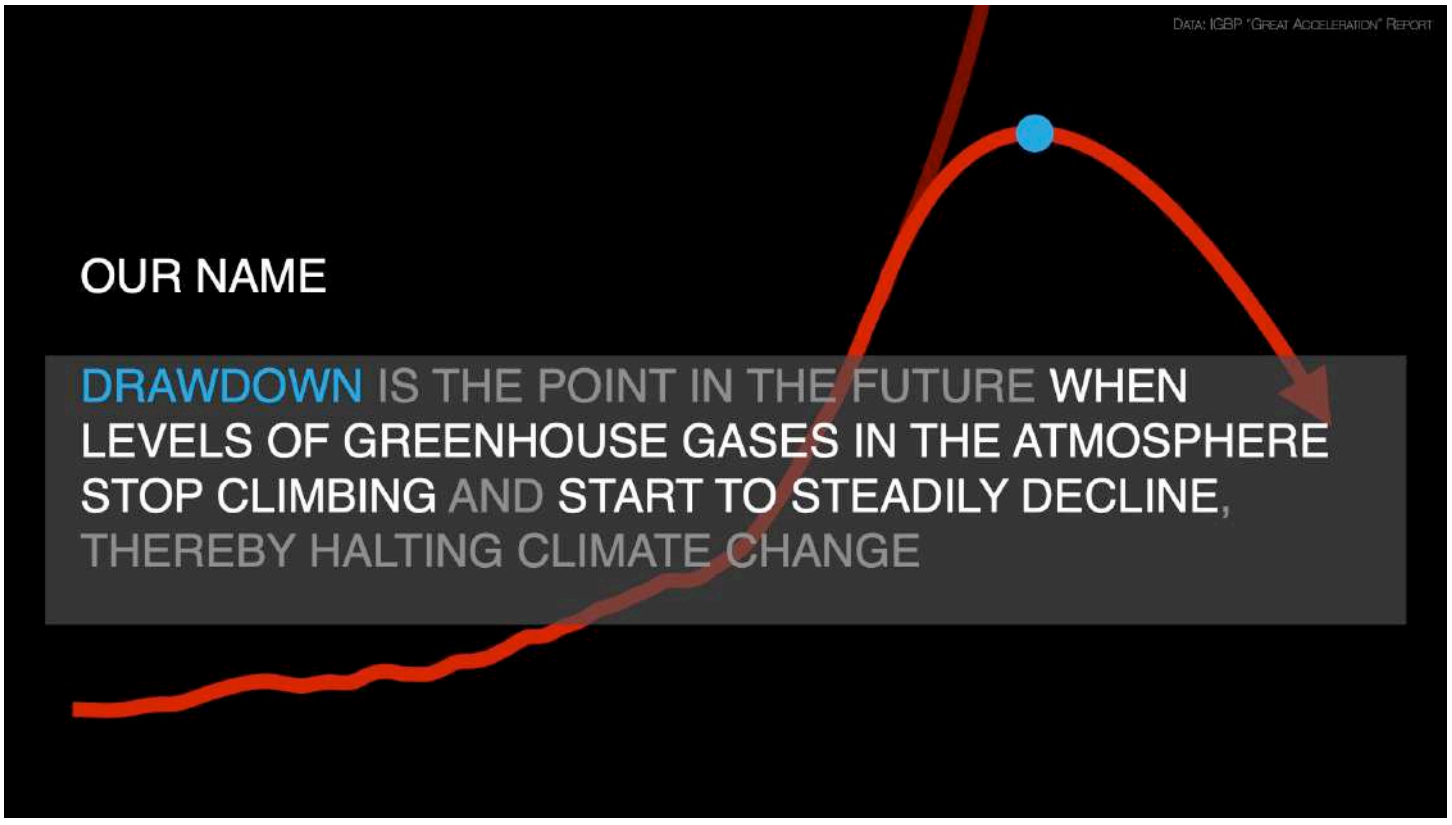
"If that ice sheet were to disintegrate, it could raise the level of the sea by more than 160 feet — a potential apocalypse, depending on exactly how fast it happened," NYT reporter Justin Gillis wrote of what some scientists predict could happen to Antarctica.

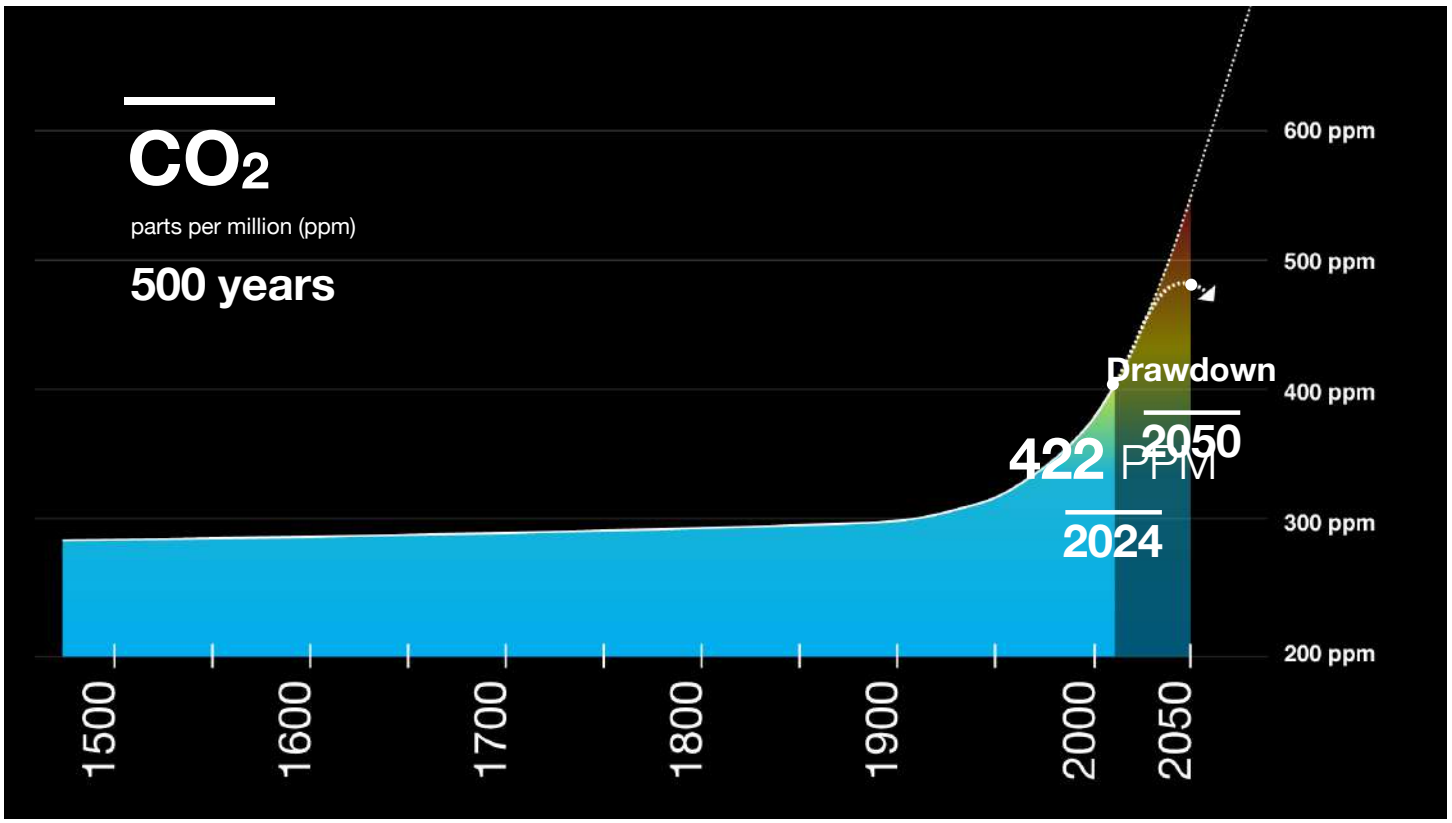
Problem
Fear
Conflict

Solutions
Possibility
Collaboration

PROJECT DRAWDOWN

The World's Leading Resource for Climate Solutions





Frischmann et al. (2020)

Project Drawdown maps and models solutions

Principle1

Principle 2

Principle 3

ELECTRICITY

- Shift Production
- Enhance Efficiency
- Improve Electrical System

ONSHORE WIND TURBINES

#6
RANK BY 2050

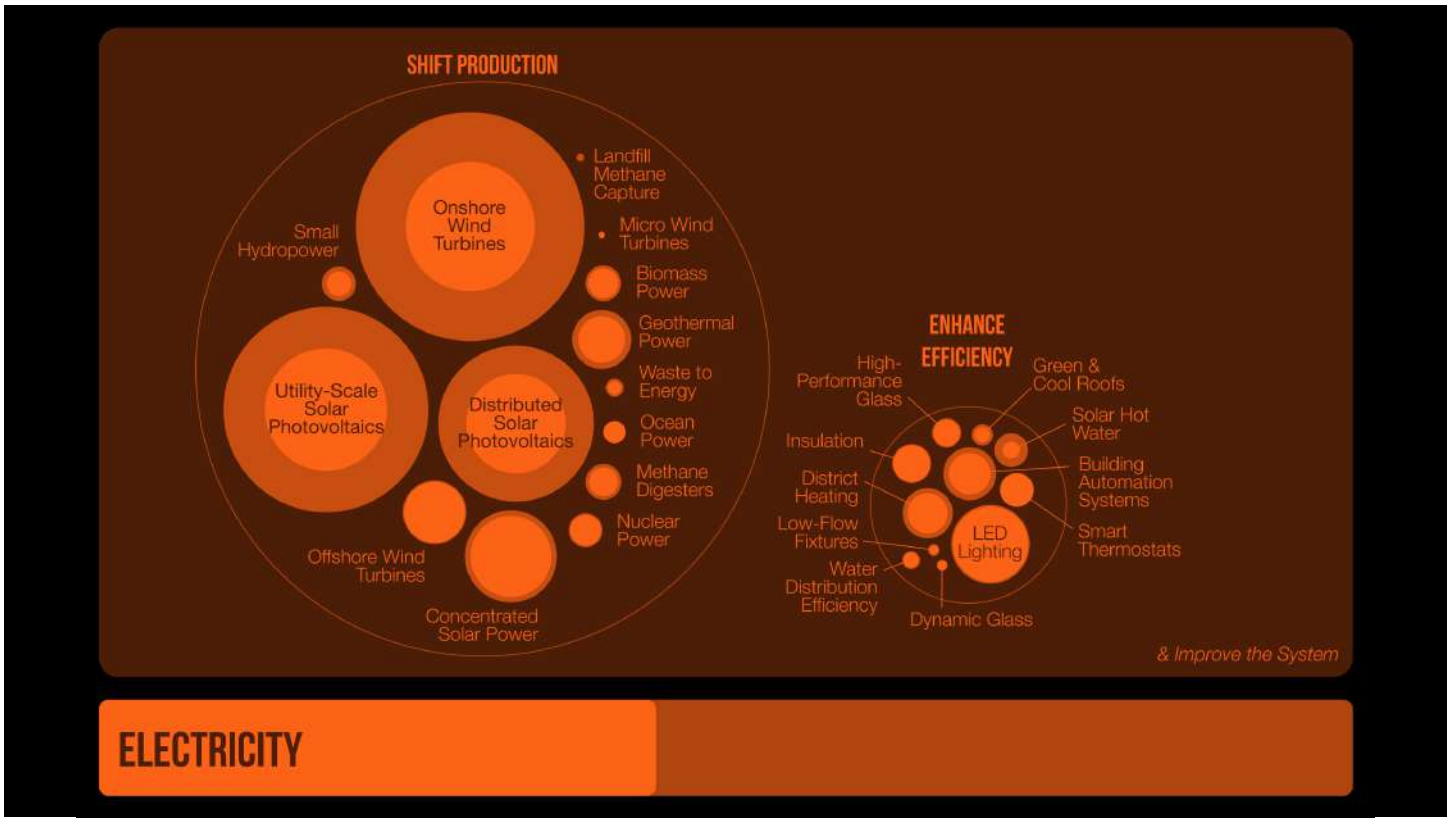
47.2GT
REDUCED CO2-eq

DISTRIBUTED SOLAR PHOTOVOLTAICS

#10
RANK BY 2050

28.0GT
REDUCED CO2-eq


OFFSHORE
WIND TURBINES
#26
RANK BY 2050
10.4GT
REDUCED CO2-eq

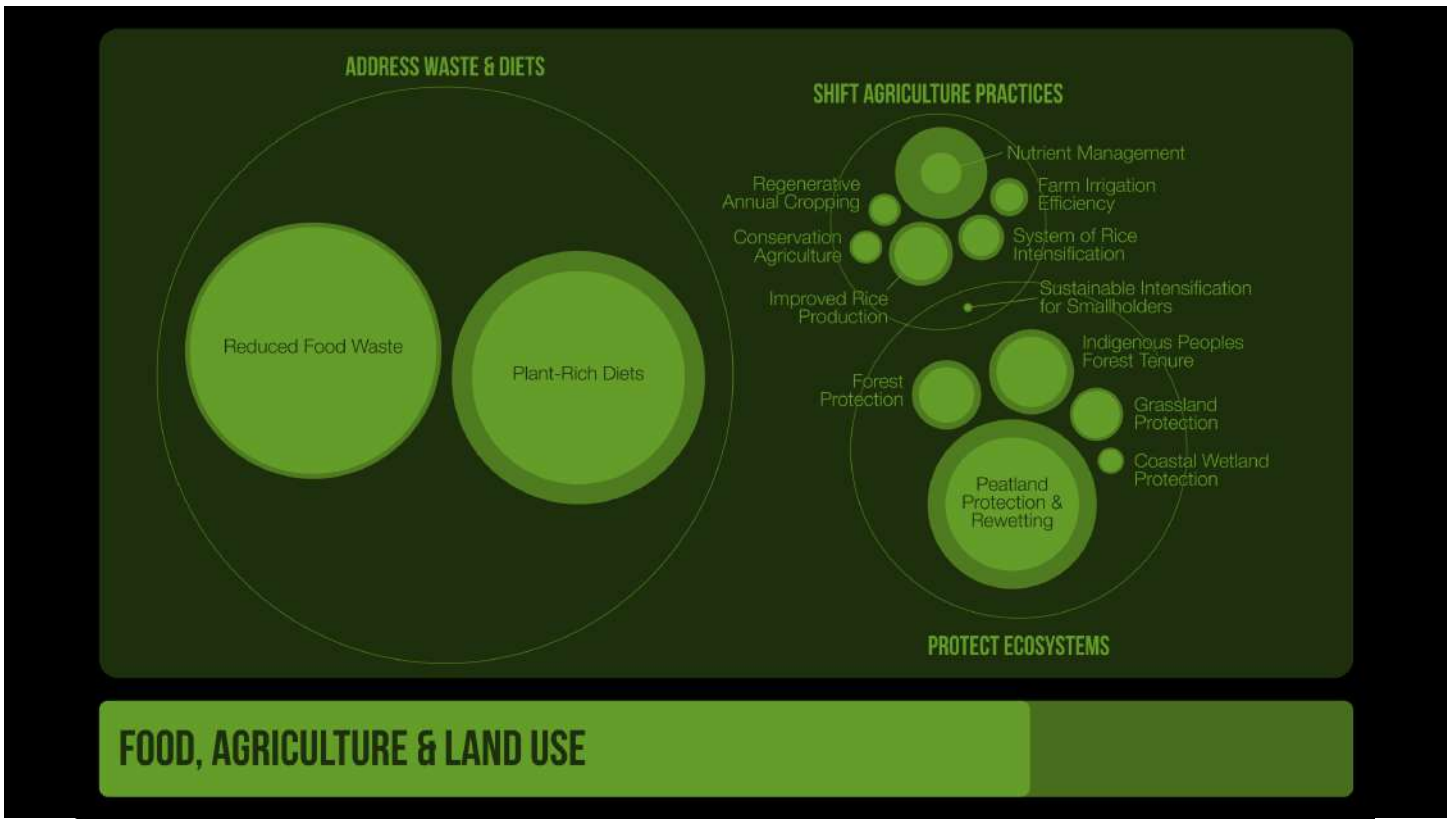

SHIFT PRODUCTION
Onshore Wind Turbines
Landfill Methane Capture
Micro Wind Turbines
Biomass Power
Geothermal Power
Waste to Energy
Ocean Power
Methane Digesters
Nuclear Power
Concentrated Solar Power
Offshore Wind Turbines
Utility-Scale Solar Photovoltaics
Distributed Solar Photovoltaics
Small Hydropower
ENHANCE EFFICIENCY
High-Performance Glass
Green & Cool Roofs
Solar Hot Water
Building Automation Systems
Smart Thermostats
LED Lighting
Dynamic Glass
Water Distribution Efficiency
Low-Flow Fixtures
District Heating
Insulation
& Improve the System
ELECTRICITY

FOOD, AGRICULTURE, LAND USE

- Address Waste & Diets
- Protect Ecosystems
- Shift Agricultural Practices


REDUCED
FOOD WASTE
#1
RANK BY 2050
87.4 GT
REDUCED CO2-eq


PLANT-RICH DIET
#3
RANK BY 2050
65.0 GT
REDUCED CO2-eq


ADDRESS WASTE & DIETS
Reduced Food Waste
Plant-Rich Diets
SHIFT AGRICULTURE PRACTICES
Nutrient Management
Regenerative Annual Cropping
Farm Irrigation Efficiency
Conservation Agriculture
System of Rice Intensification
Improved Rice Production
Sustainable Intensification for Smallholders
Indigenous Peoples Forest Tenure
Forest Protection
Grassland Protection
Coastal Wetland Protection
Peatland Protection & Rewetting
PROTECT ECOSYSTEMS
FOOD, AGRICULTURE & LAND USE

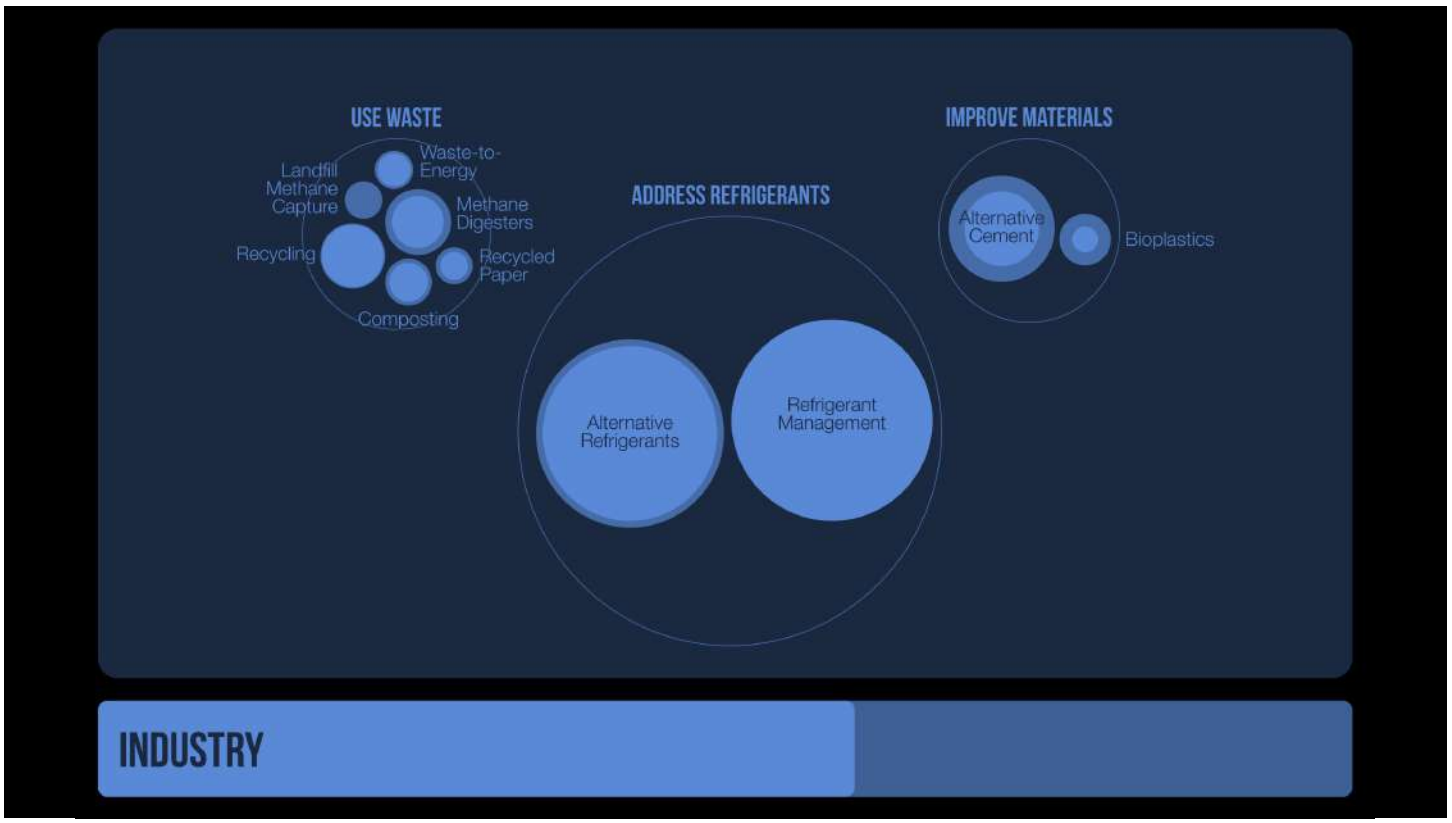

INDUSTRY
DRAWDOWN 2020

INDUSTRY

- Use Waste
- Address Refrigerants
- Improve Materials


COMPOSTING
#57
RANK BY 2050
2.1GT
REDUCED CO2

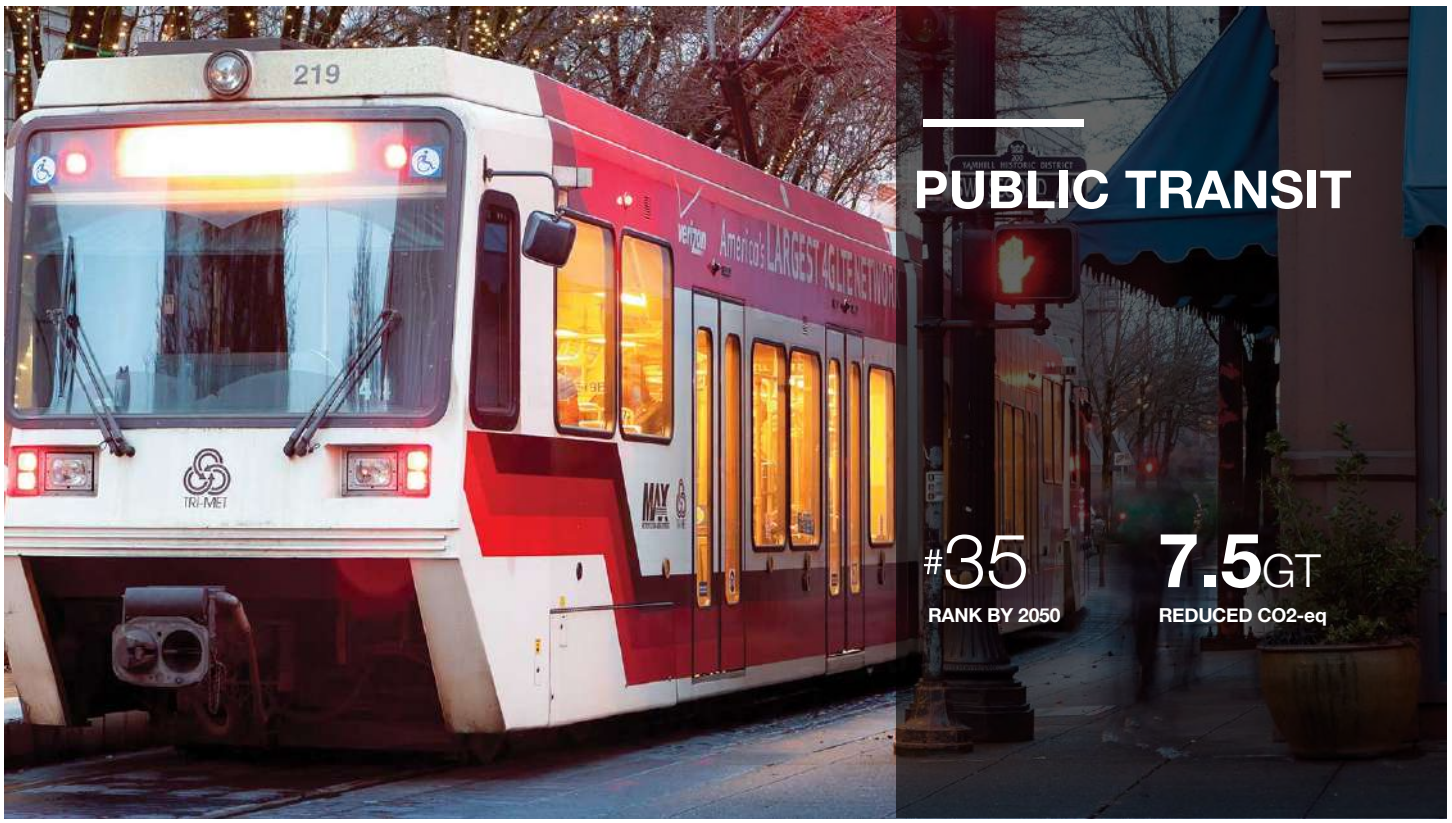

RECYCLED MATERIALS


USE WASTE
Waste-to-Energy
Landfill Methane Capture
Methane Digesters
Recycling
Recycled Paper
Composting
ADDRESS REFRIGERANTS
Alternative Refrigerants
Refrigerant Management
IMPROVE MATERIALS
Alternative Cement
Bioplastics
INDUSTRY


DRAWDOWN 2020
TRANSPORTATION

TRANSPORTATION

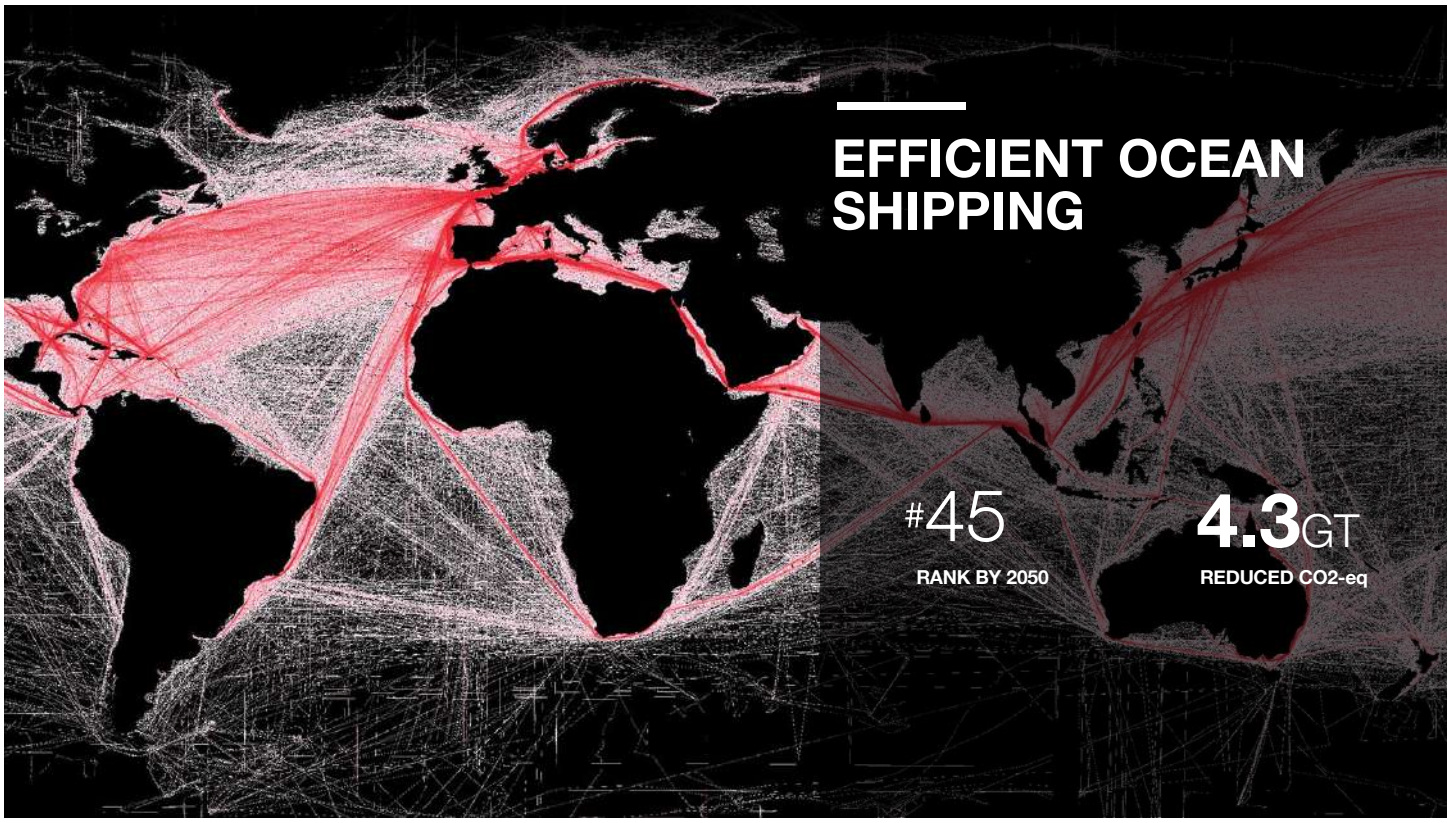
- Shift to Alternatives
- Enhance Efficiency
- Electrify Vehicles



PUBLIC TRANSIT

#35
RANK BY 2050

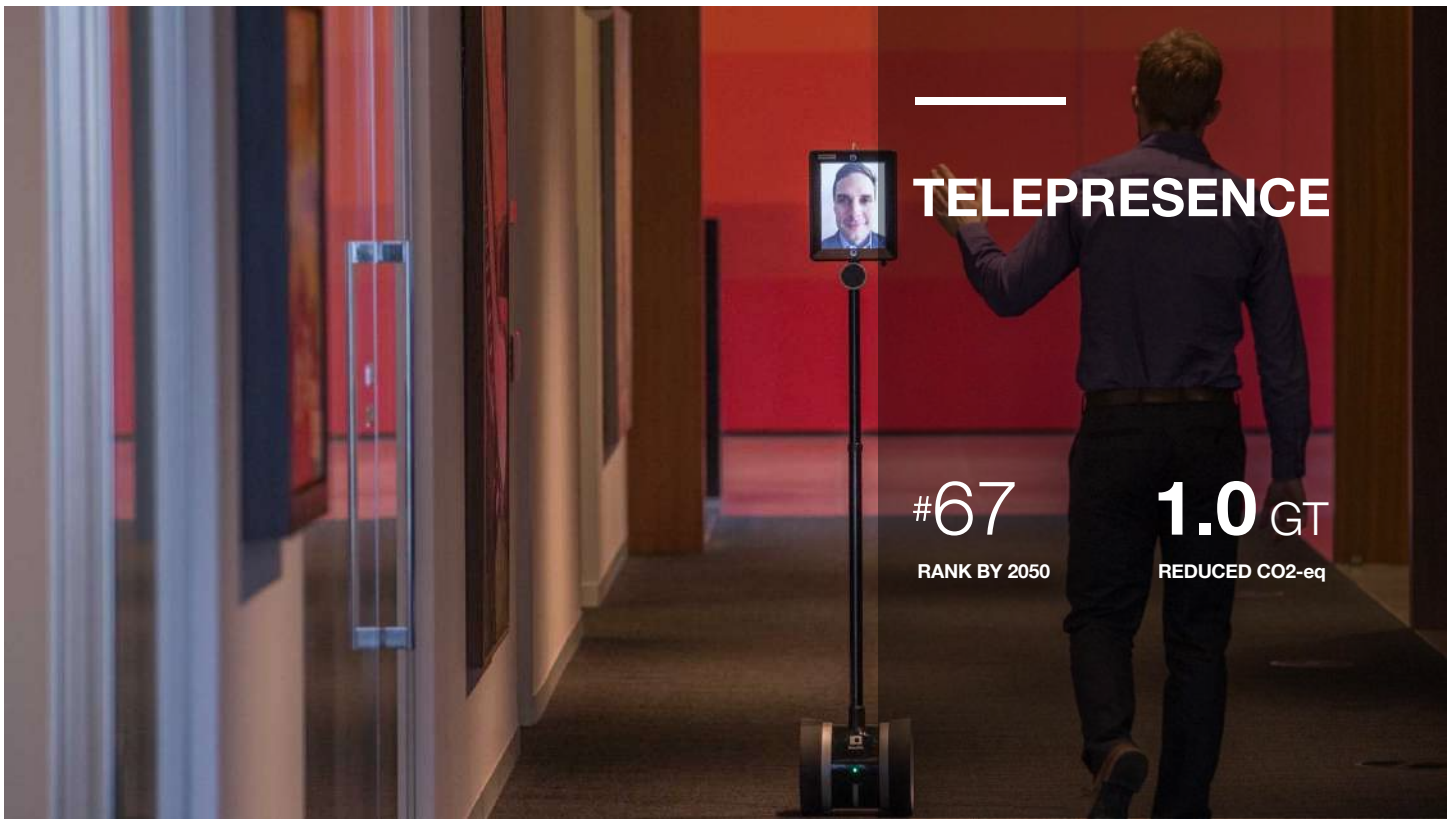
7.5GT
REDUCED CO2-eq



EFFICIENT OCEAN SHIPPING

#45
RANK BY 2050

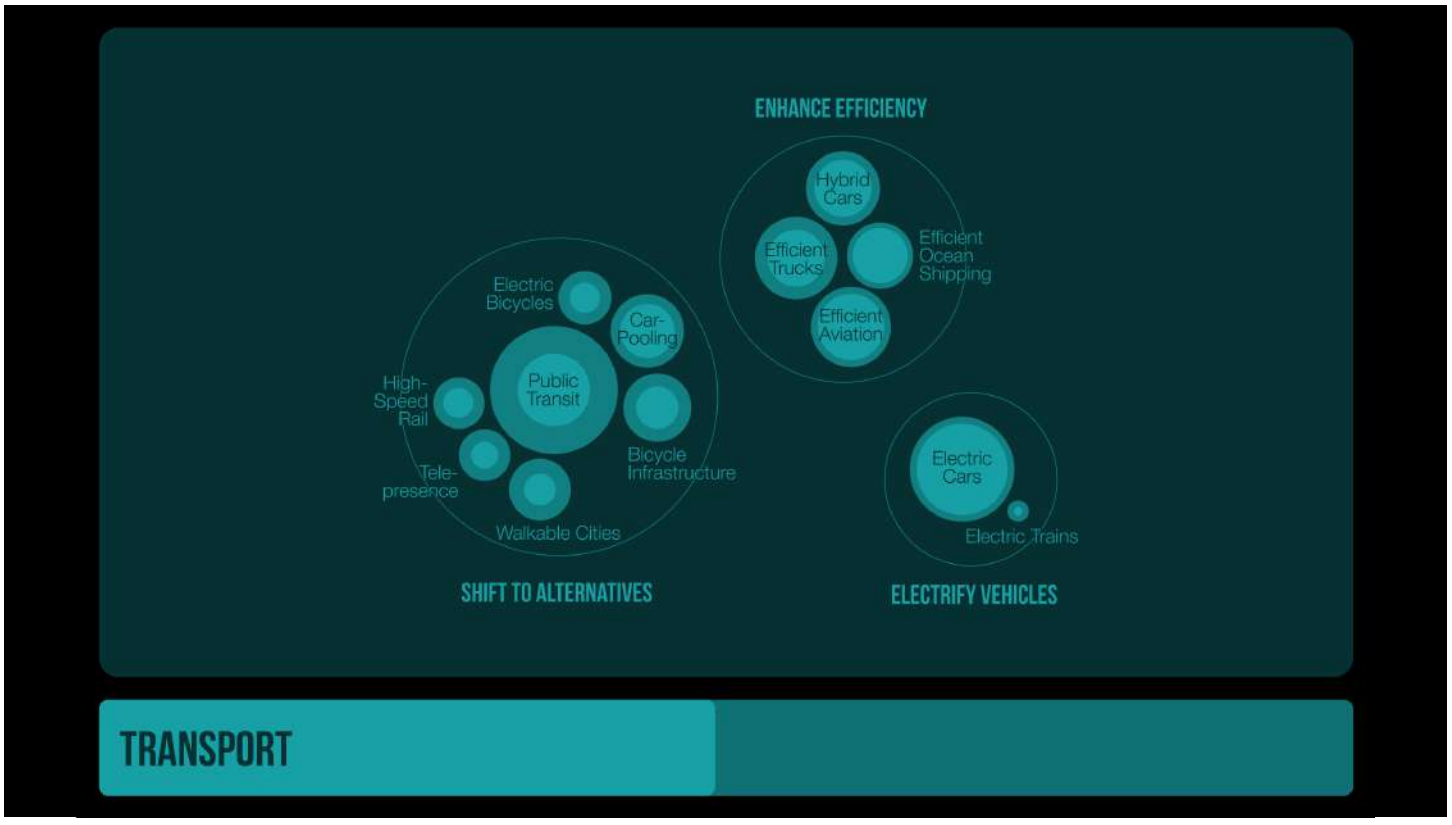
4.3GT
REDUCED CO2-eq

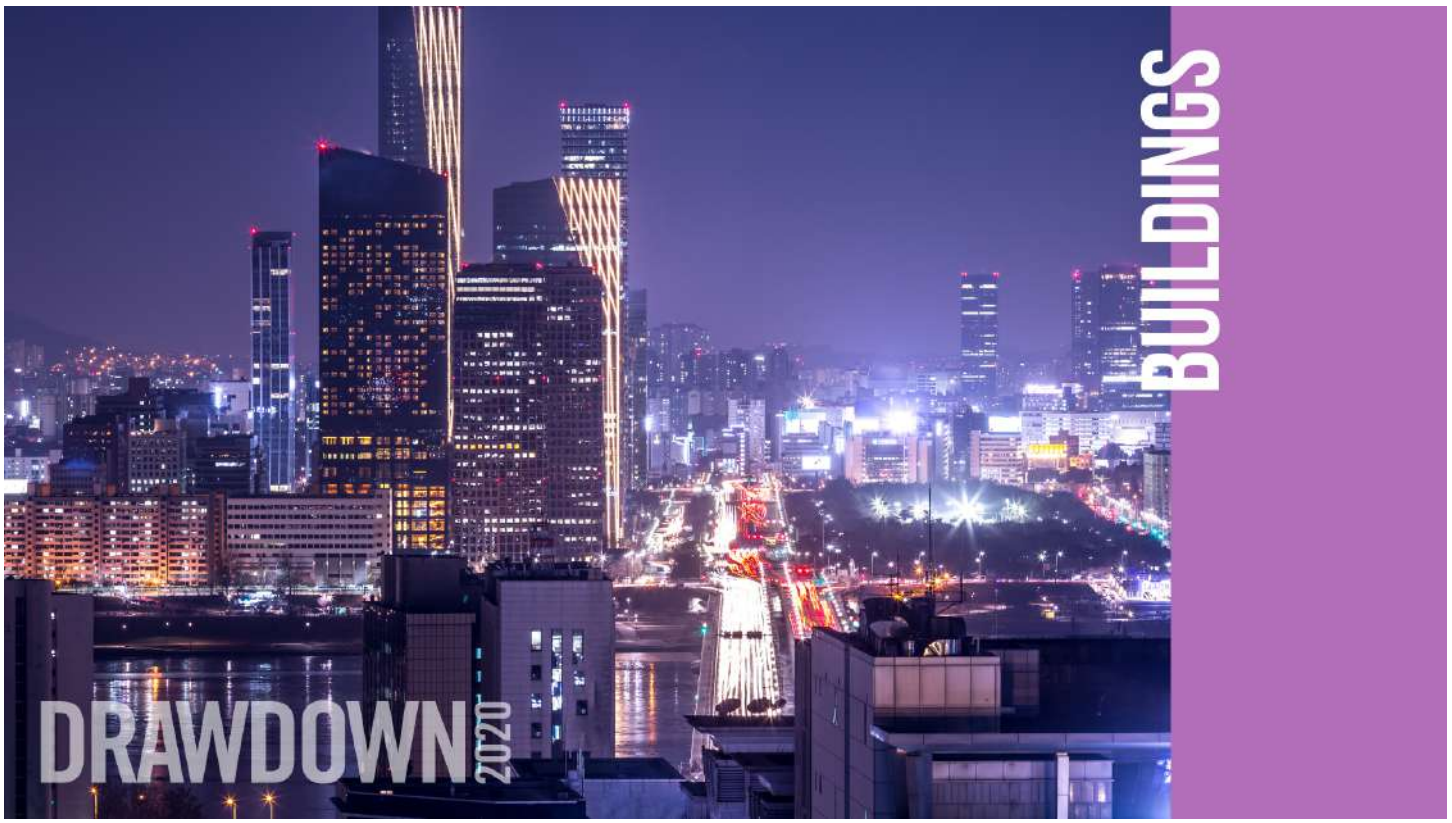


TELEPRESENCE

#67
RANK BY 2050

1.0 GT
REDUCED CO2-eq





BUILDINGS

- Shift to Alternatives
- Enhance Efficiency
- Address Refrigerants

IMPROVED CLEAN COOKSTOVES

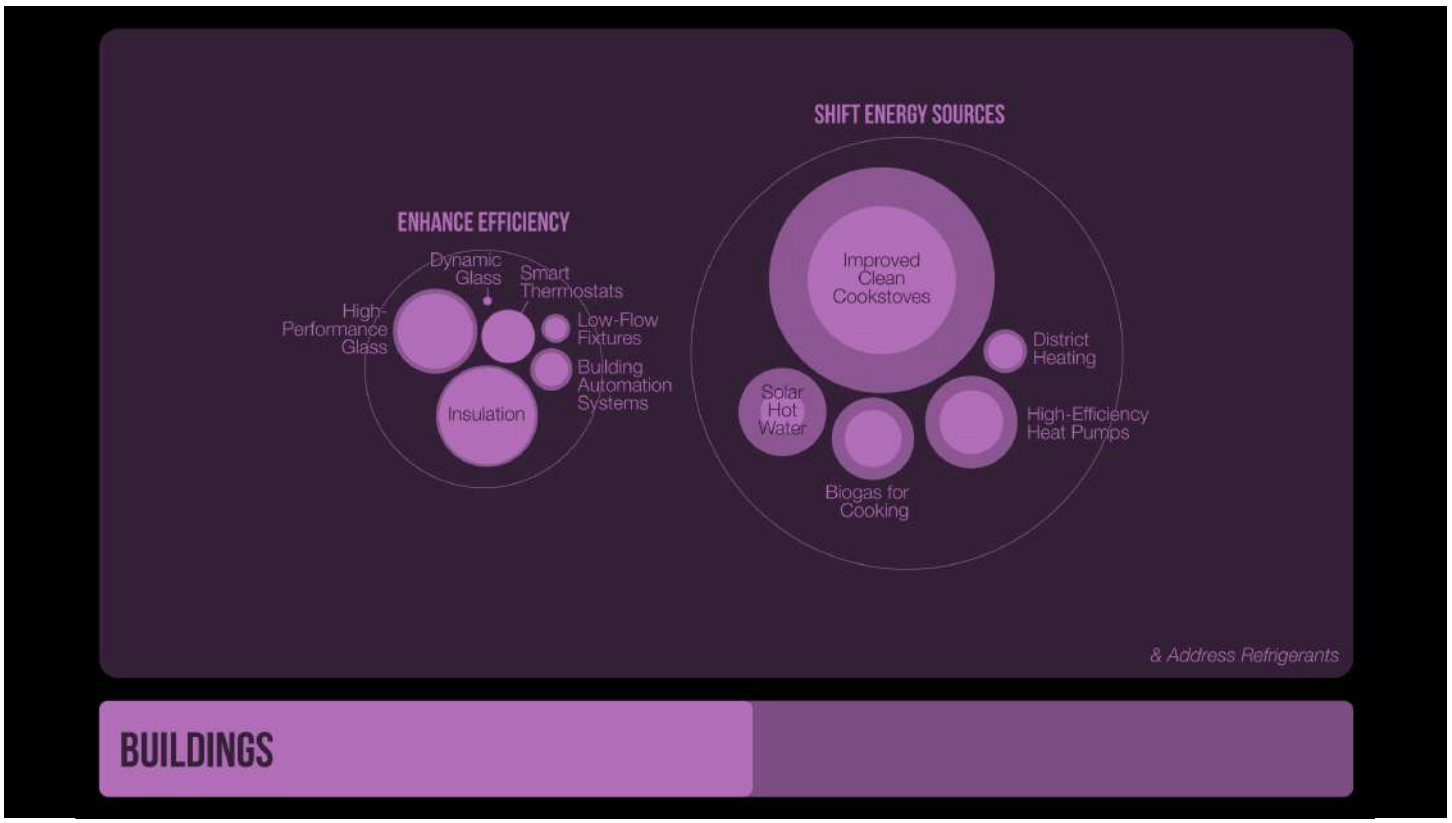
#9
RANK BY 2050

31.3 GT
REDUCED CO2-eq

INSULATION

#16
RANK BY 2050

17.0GT
REDUCED CO2-eq


ENHANCE EFFICIENCY
Dynamic Glass
Smart Thermostats
High-Performance Glass
Low-Flow Fixtures
Building Automation Systems
Insulation
SHIFT ENERGY SOURCES
Improved Clean Cookstoves
District Heating
Solar Hot Water
High-Efficiency Heat Pumps
Biogas for Cooking
& Address Refrigerants
BUILDINGS


LAND SINKS
DRAWDOWN 2020

LAND-BASED SINKS

- Shift Agricultural Practices
- Protect and Restore Ecosystems
- Use Degraded Land
- Address Waste and Diets

MANAGED GRAZING

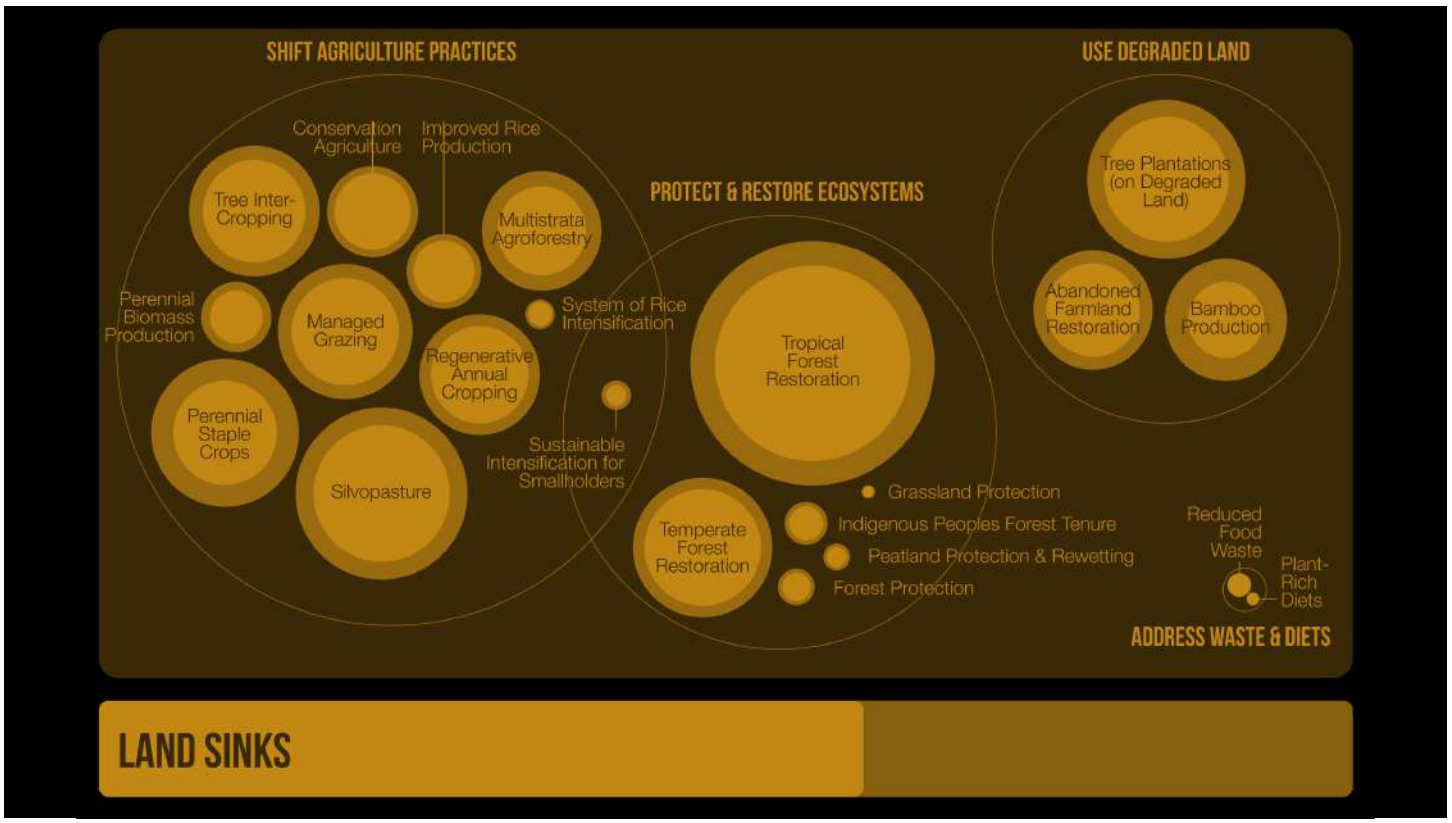
#17
RANK BY 2050

16.4 GT
REDUCED CO2-eq

FOREST PROTECTION

#41
RANK BY 2050

5.5 GT
REDUCED CO2-eq


SHIFT AGRICULTURE PRACTICES
USE DEGRADED LAND
Conservation Agriculture
Improved Rice Production
Tree Inter-Cropping
Multistrata Agroforestry
PROTECT & RESTORE ECOSYSTEMS
Tree Plantations (on Degraded Land)
Perennial Biomass Production
Managed Grazing
System of Rice Intensification
Abandoned Farmland Restoration
Bamboo Production
Regenerative Annual Cropping
Tropical Forest Restoration
Perennial Staple Crops
Sustainable Intensification for Smallholders
Silvopasture
Grassland Protection
Temperate Forest Restoration
Indigenous Peoples Forest Tenure
Peatland Protection & Rewetting
Forest Protection
Reduced Food Waste
Plant-Rich Diets
ADDRESS WASTE & DIETS
LAND SINKS


COASTAL AND OCEAN SINKS
DRAWDOWN 2020

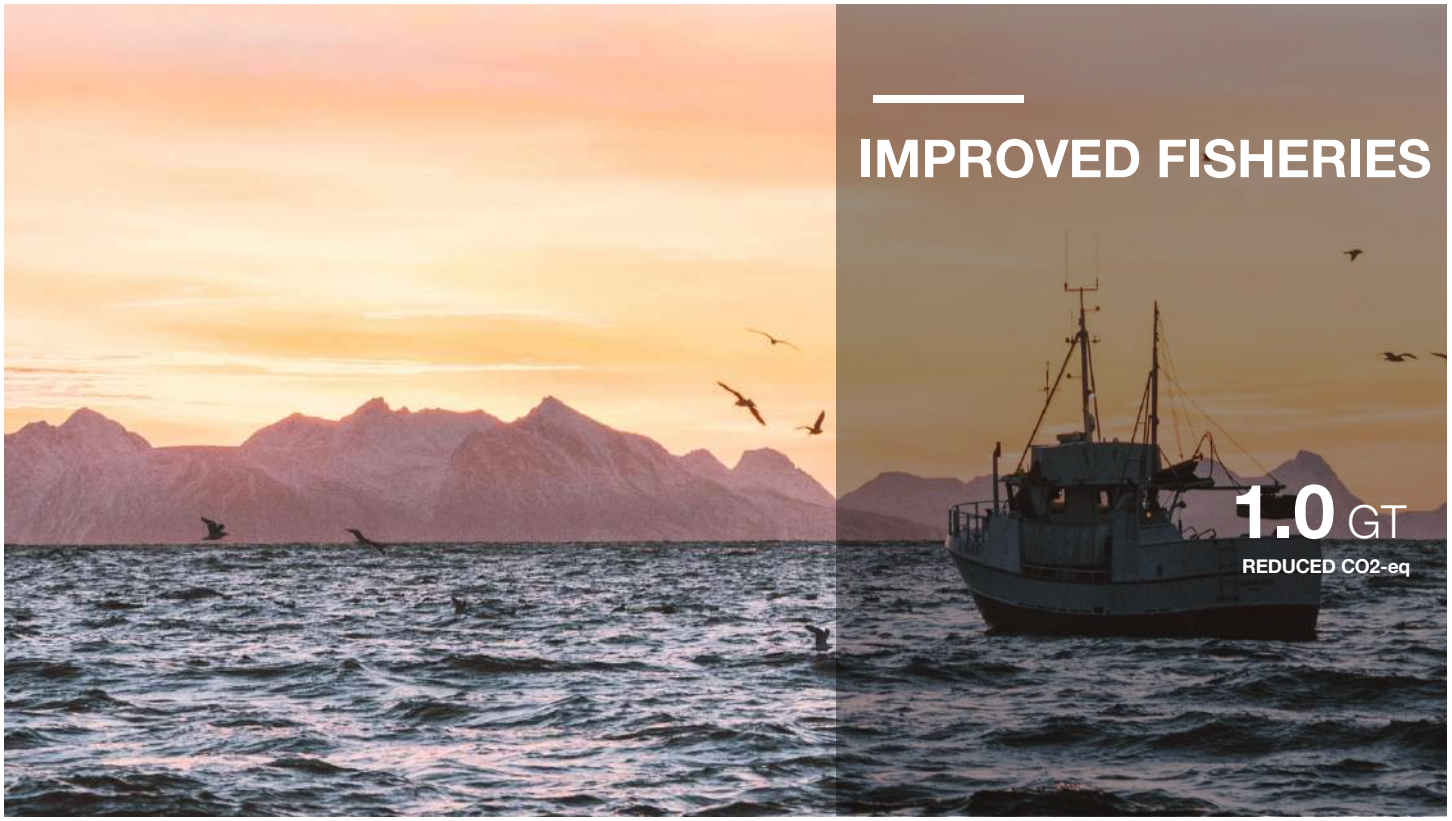
COASTAL WETLAND RESTORATION

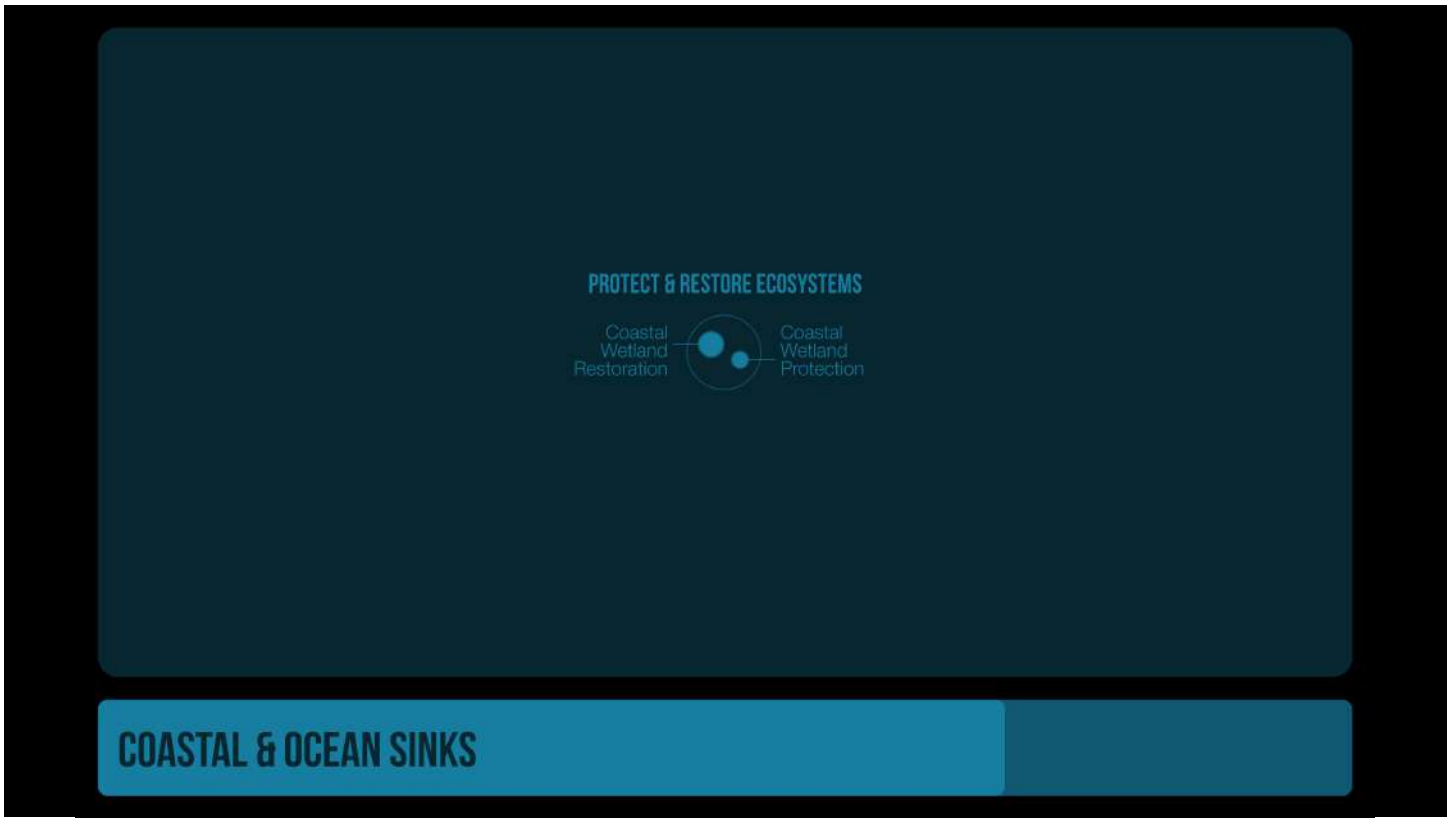
#71
RANK BY 2050

0.8 GT
REDUCED CO2-eq

SEAWEED FARMING

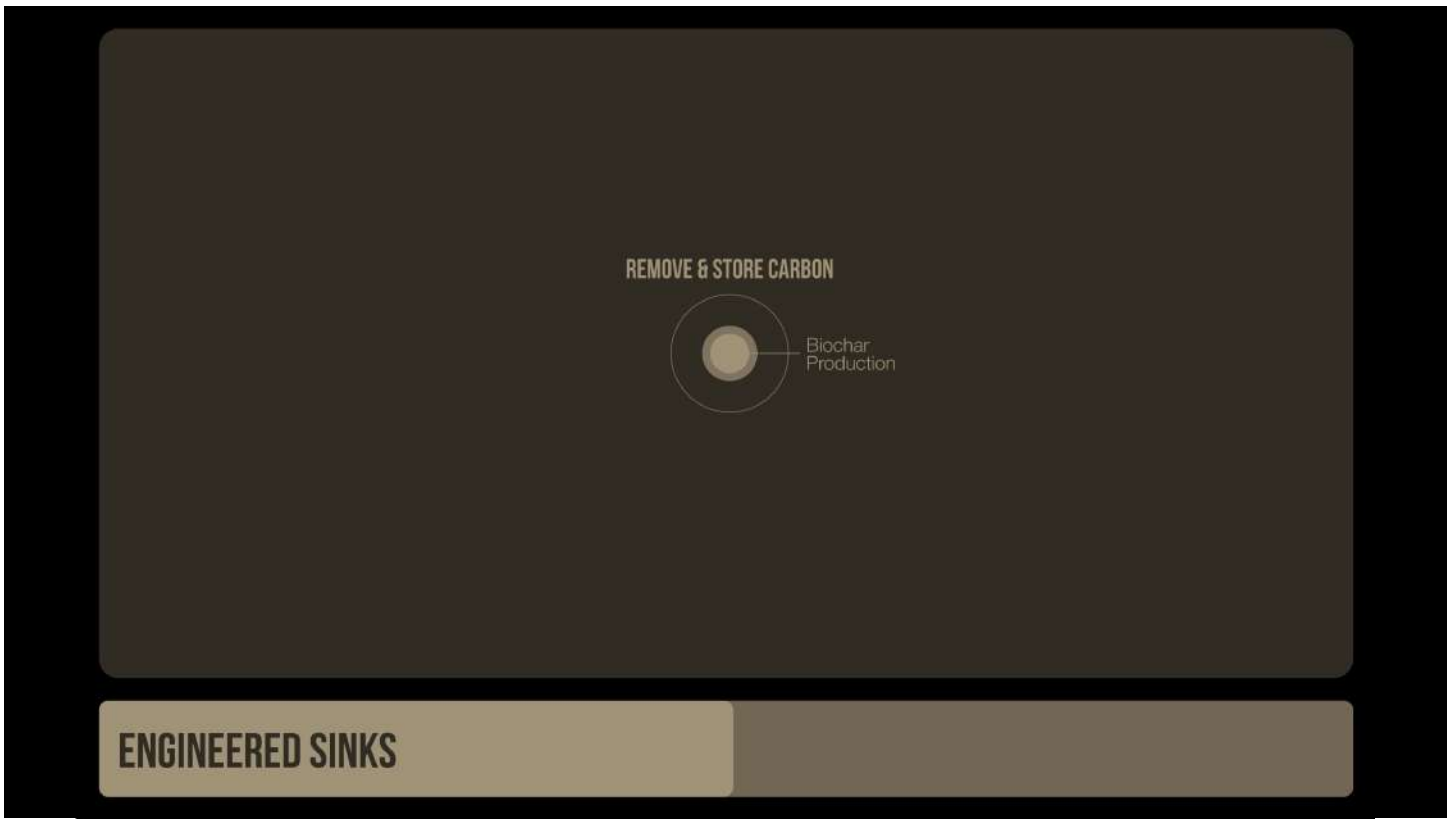
2.5 GT
REDUCED CO2-eq


IMPROVED FISHERIES
1.0 GT
REDUCED CO2-eq


PROTECT & RESTORE ECOSYSTEMS
Coastal Wetland Restoration
Coastal Wetland Protection
COASTAL & OCEAN SINKS


DRAWDOWN 2020
ENGINEERED SINKS


BIOCHAR
PRODUCTION
#41
RANK BY 2050
2.2 GT
REDUCED CO2-eq

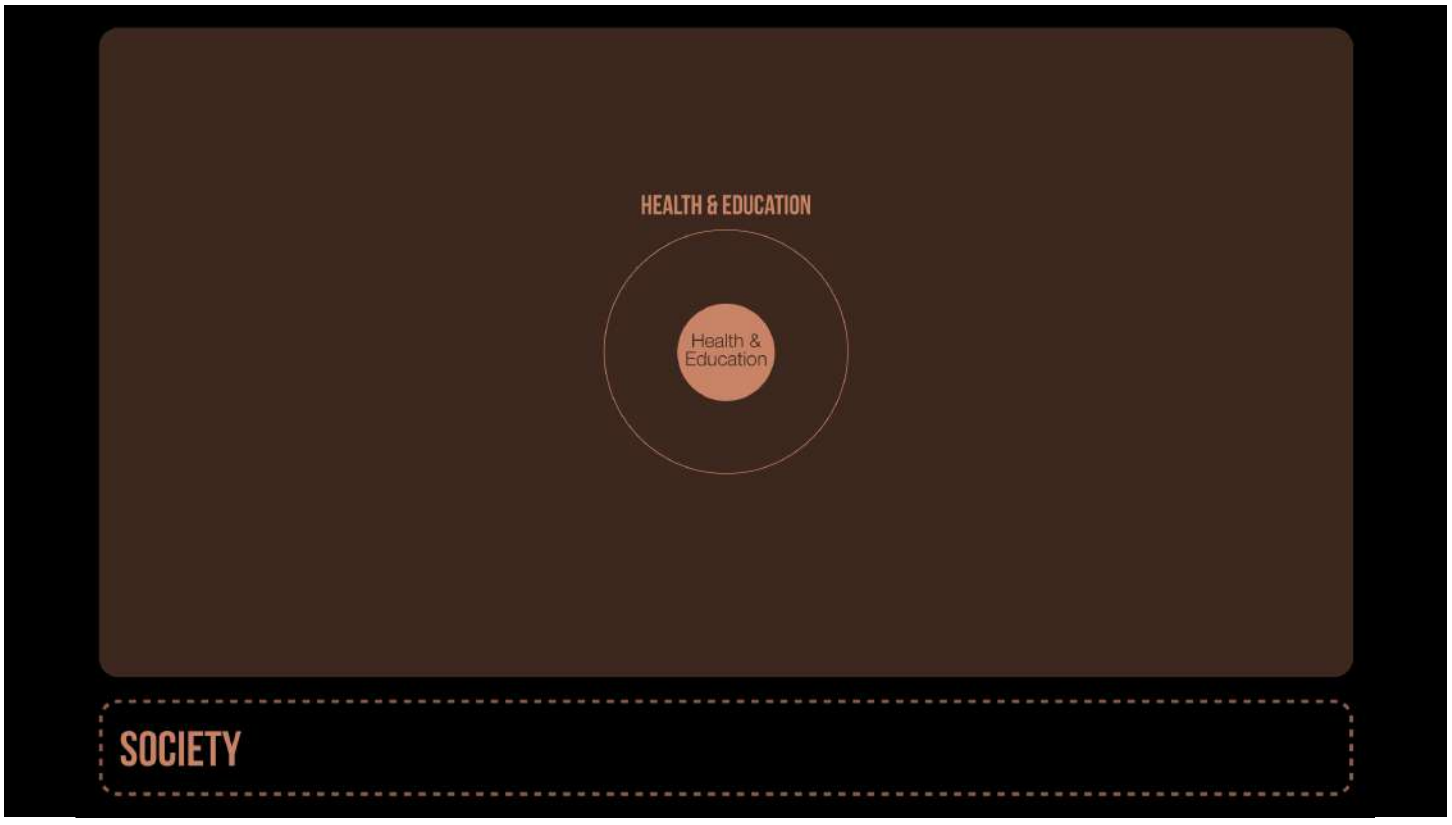

REMOVE & STORE CARBON
Biochar Production
ENGINEERED SINKS


HEALTH AND EDUCATION
DRAWDOWN

HEALTH & EDUCATION

#2
RANK BY 2050

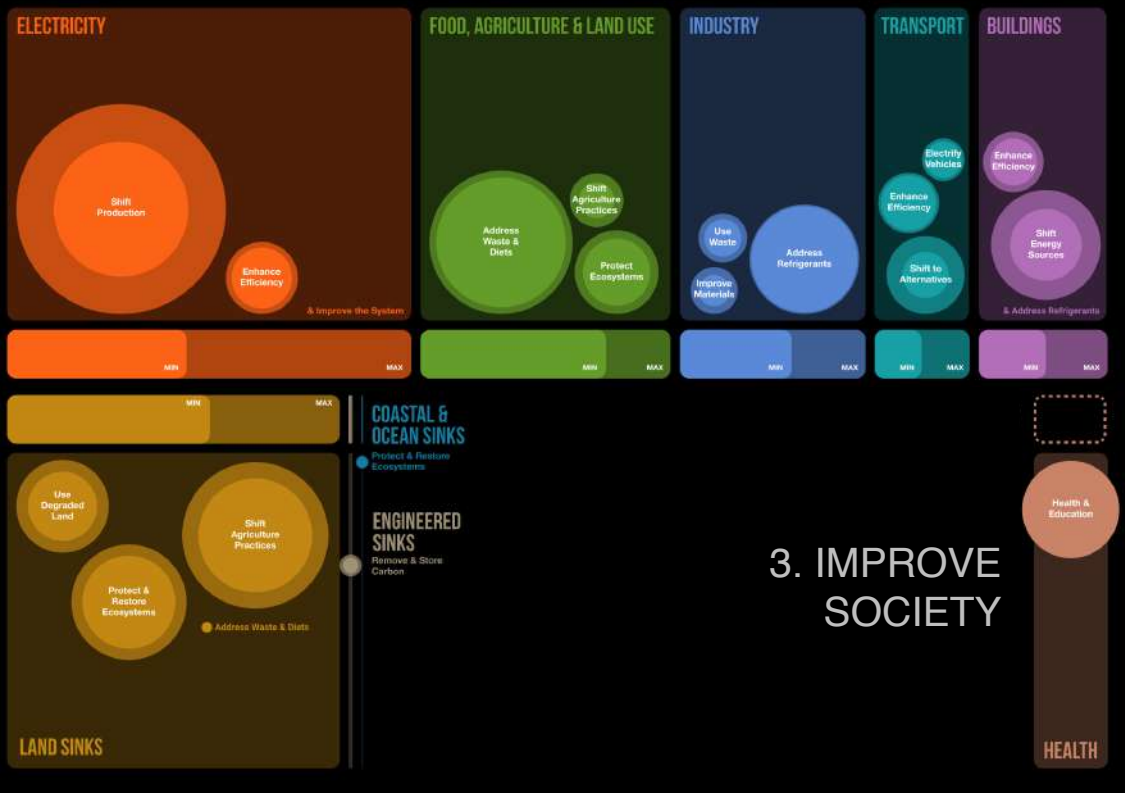
85.4 GT
REDUCED CO2-eq

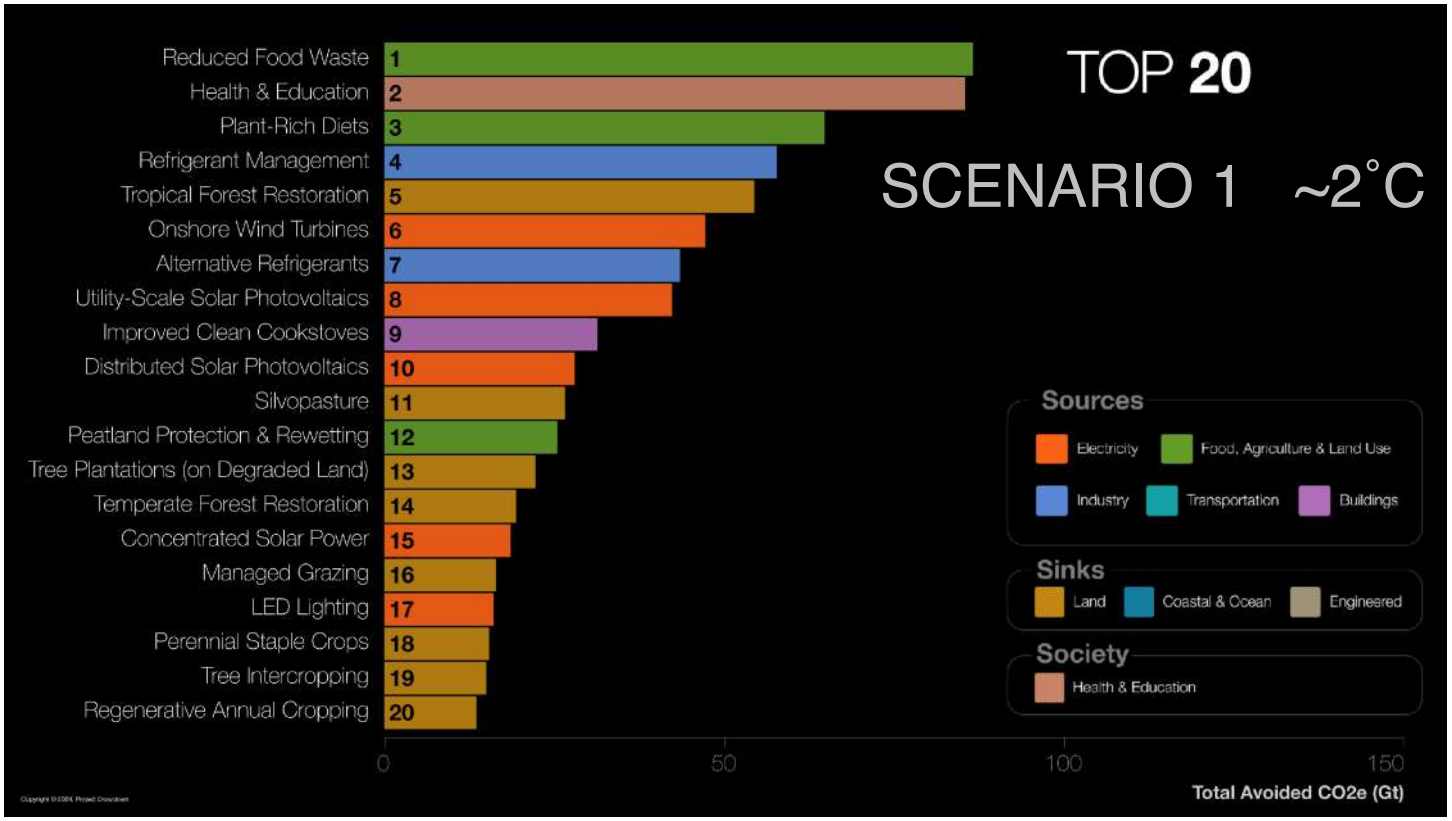


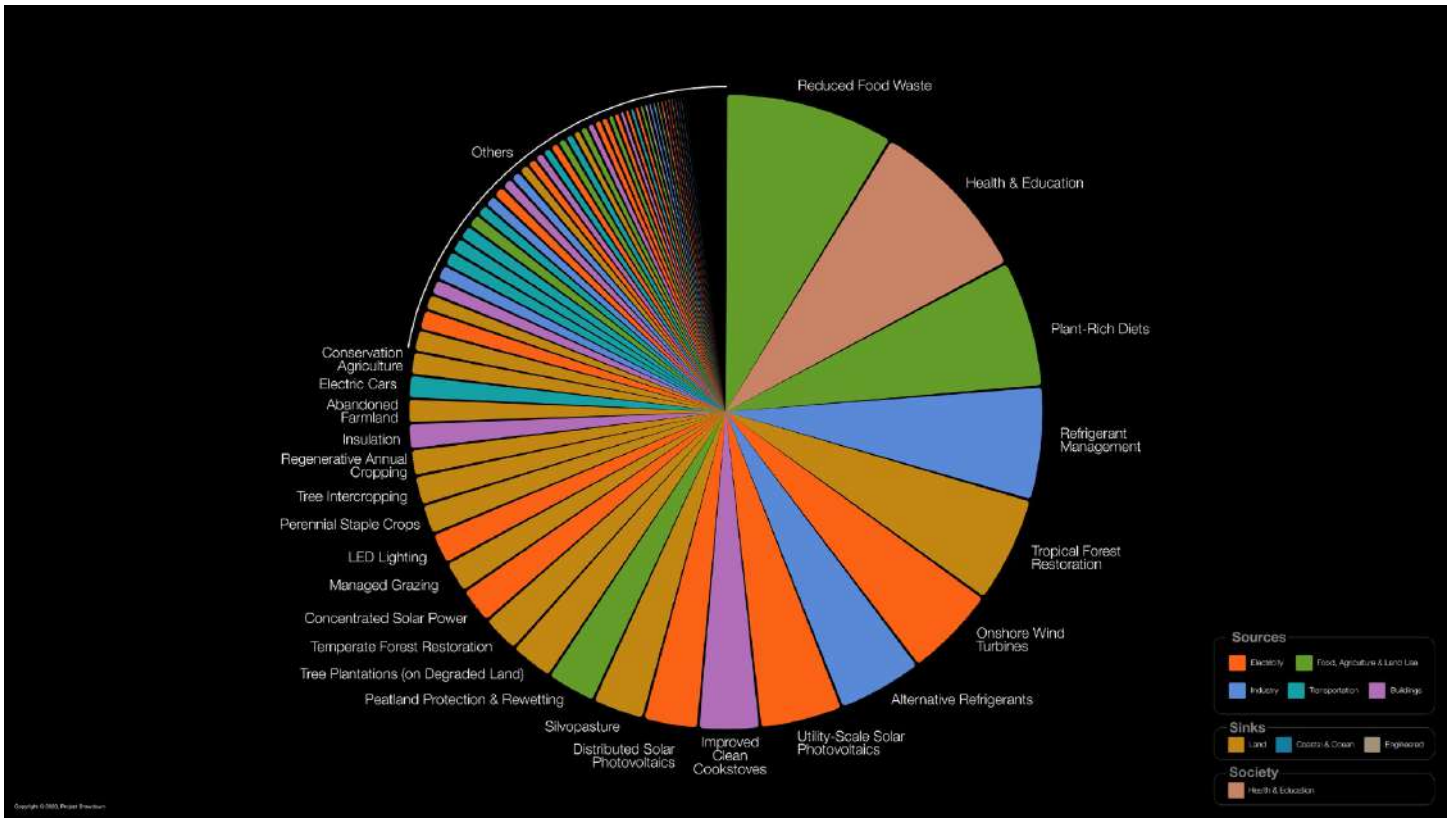
1. REDUCE SOURCES

2. SUPPORT SINKS

3. IMPROVE SOCIETY




TOP 20
SCENARIO 1 ~2°C
Reduced Food Waste 1
Health & Education 2
Plant-Rich Diets 3
Refrigerant Management 4
Tropical Forest Restoration 5
Onshore Wind Turbines 6
Alternative Refrigerants 7
Utility-Scale Solar Photovoltaics 8
Improved Clean Cookstoves 9
Distributed Solar Photovoltaics 10
Silvopasture 11
Peatland Protection & Rewetting 12
Tree Plantations (on Degraded Land) 13
Temperate Forest Restoration 14
Concentrated Solar Power 15
Managed Grazing 16
LED Lighting 17
Perennial Staple Crops 18
Tree Intercropping 19
Regenerative Annual Cropping 20
0
50
100
150
Total Avoided CO2e (Gt)
Sources
Electricity
Food, Agriculture & Land Use
Industry
Transportation
Buildings
Sinks
Land
Coastal & Ocean
Engineered
Society
Health & Education


Reduced Food Waste
Health & Education
Plant-Rich Diets
Refrigerant Management
Tropical Forest Restoration
Onshore Wind Turbines
Alternative Refrigerants
Utility-Scale Solar Photovoltaics
Improved Clean Cookstoves
Distributed Solar Photovoltaics
Silvopasture
Peatland Protection & Rewetting
Tree Plantations (on Degraded Land)
Temperate Forest Restoration
Concentrated Solar Power
Managed Grazing
LED Lighting
Perennial Staple Crops
Tree Intercropping
Regenerative Annual Cropping
Insulation
Abandoned Farmland
Electric Cars
Conservation Agriculture
Others
Sources
Sinks
Society

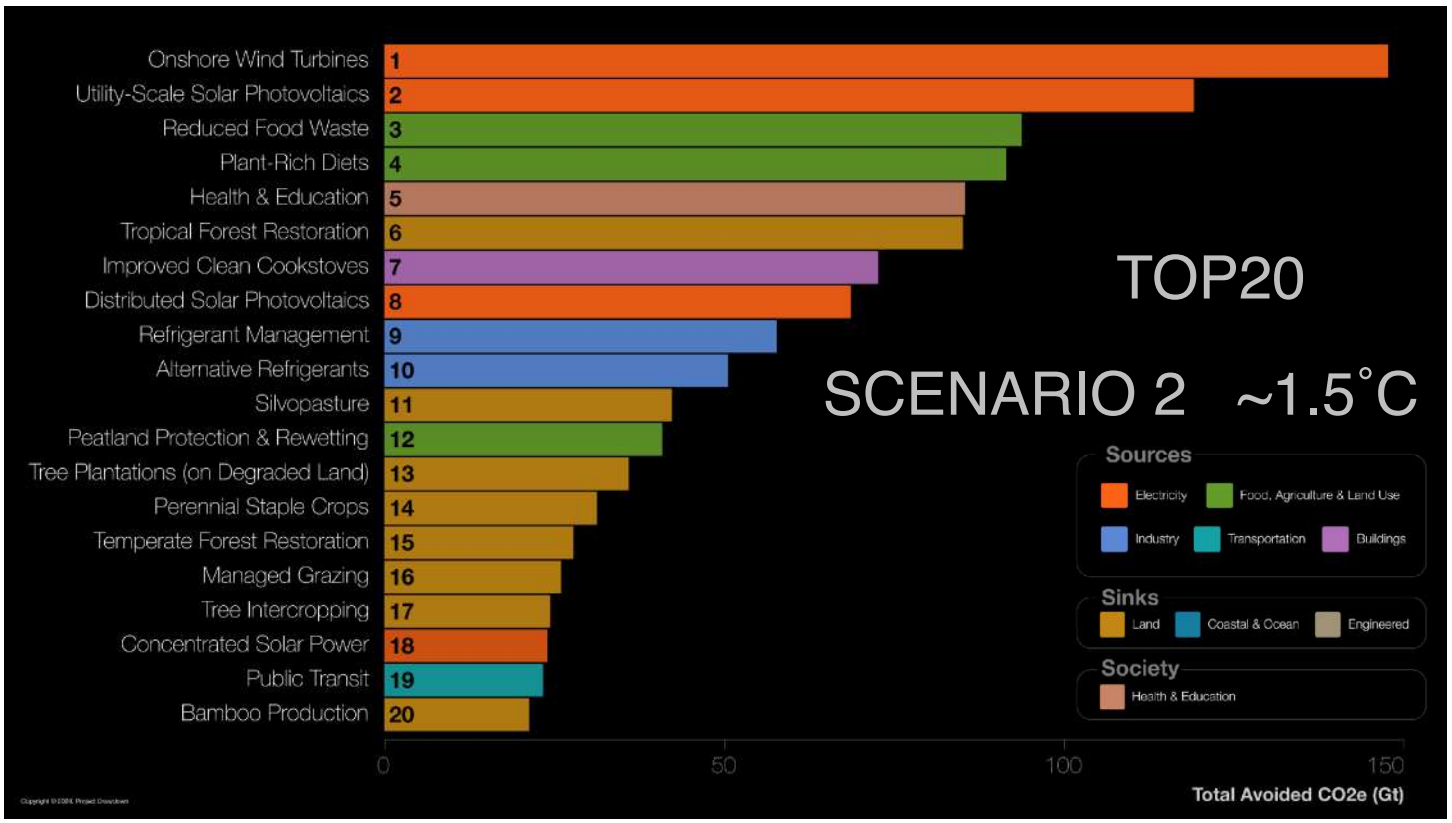
PREVENTS 993.8 GT-CO_2

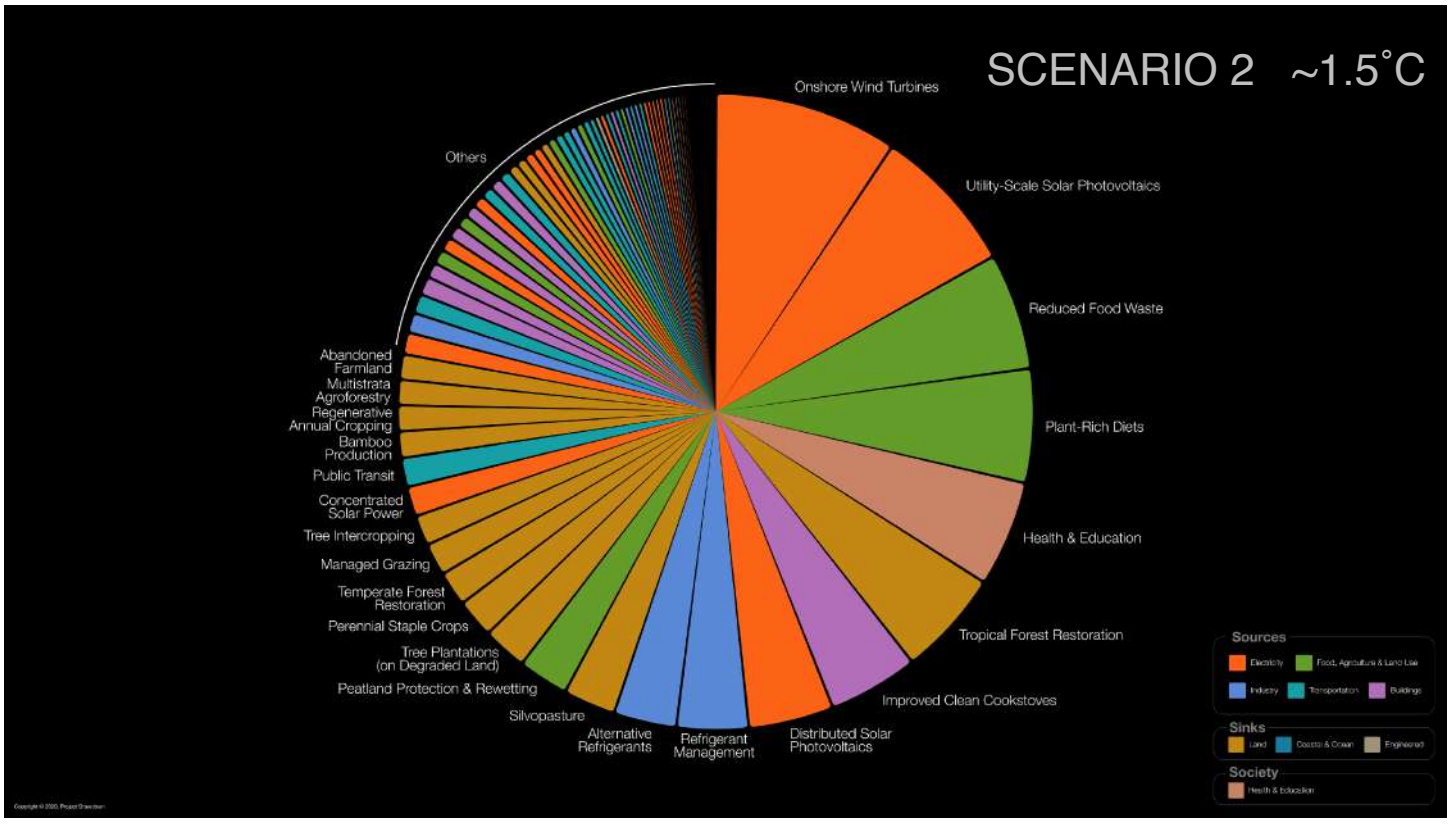
INITIAL COSTS $22.5 TRILLION
TOTAL SAVINGS $95.1 TRILLION

4.2X RETURN ON INVESTMENT

Is **Drawdown**
possible by 2050?

Only when we **challenge systems**

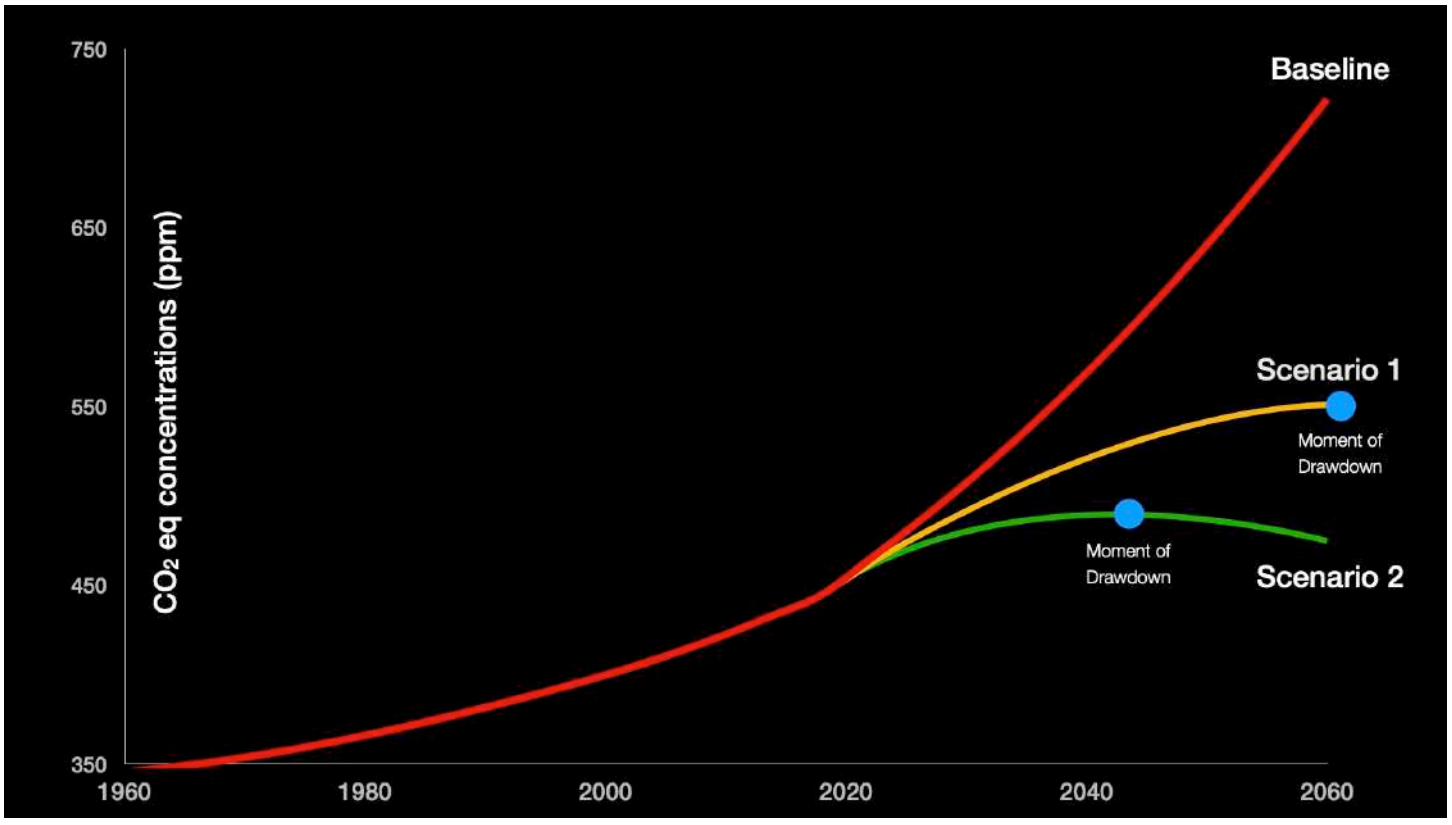

Onshore Wind Turbines 1
Utility-Scale Solar Photovoltaics 2
Reduced Food Waste 3
Plant-Rich Diets 4
Health & Education 5
Tropical Forest Restoration 6
Improved Clean Cookstoves 7
Distributed Solar Photovoltaics 8
Refrigerant Management 9
Alternative Refrigerants 10
Silvopasture 11
Peatland Protection & Rewetting 12
Tree Plantations (on Degraded Land) 13
Perennial Staple Crops 14
Temperate Forest Restoration 15
Managed Grazing 16
Tree Intercropping 17
Concentrated Solar Power 18
Public Transit 19
Bamboo Production 20
TOP20
SCENARIO 2 ~1.5˚C
Sources
Electricity
Food, Agriculture & Land Use
Industry
Transportation
Buildings
Sinks
Land
Coastal & Ocean
Engineered
Society
Health & Education
0
50
100
150
Total Avoided CO2e (Gt)

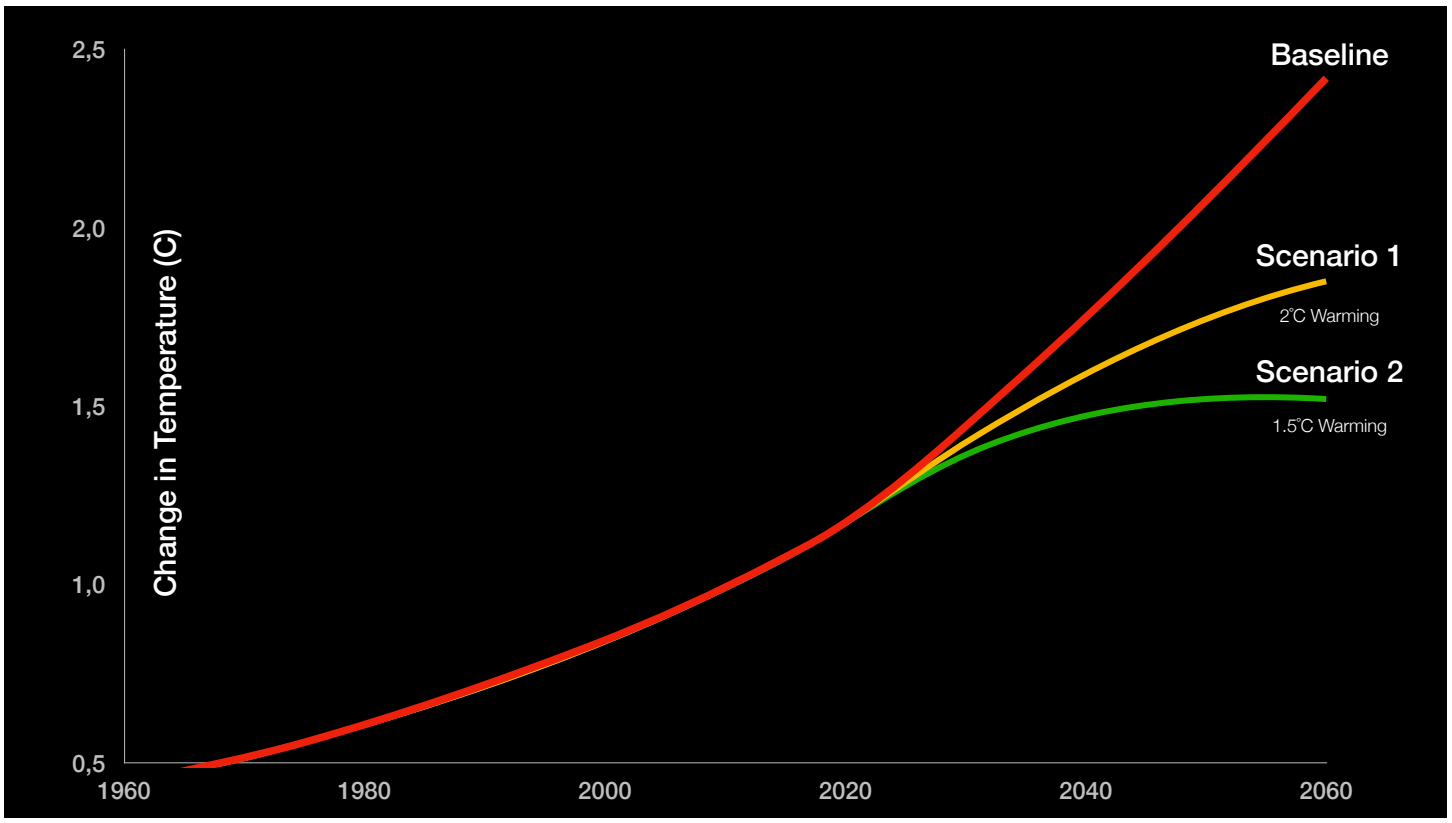

SCENARIO 2 ~1.5˚C
Onshore Wind Turbines
Utility-Scale Solar Photovoltaics
Reduced Food Waste
Plant-Rich Diets
Health & Education
Tropical Forest Restoration
Improved Clean Cookstoves
Distributed Solar Photovoltaics
Refrigerant Management
Alternative Refrigerants
Silvopasture
Peatland Protection & Rewetting
Tree Plantations (on Degraded Land)
Perennial Staple Crops
Temperate Forest Restoration
Managed Grazing
Tree Intercropping
Concentrated Solar Power
Public Transit
Bamboo Production
Regenerative Annual Cropping
Multistrata Agroforestry
Abandoned Farmland
Others
Sources
Sinks
Society

PREVENTS 1,580.4 GT-CO_2

INITIAL COSTS $28.4 TRILLION
TOTAL SAVINGS $145.5 TRILLION

5.1X RETURN ON INVESTMENT





WE HAVE ENOUGH SOLUTIONS TO DO THE JOB

WE CAN REACH DRAWDOWN BY MIDCENTURY IF WE SCALE SOLUTIONS ALREADY IN HAND, TODAY

MORE SOLUTIONS ARE NEEDED, BUT THE TOOLS WE NEED ARE IN HAND

NOW IS BETTER THAN NEW


MARINE
PERMACULTURE


BUILDING
WITH WOOD

A COW WALKS ONTO A BEACH

ENERGY
ROOFTOP SOLAR

#10

RANKING AND RESULTS BY 2050

24.6 GIGATONS	$453.1 BILLION	$3.46 TRILLION
REDUCED CO2	NET COST	NET SAVINGS

The year was 1884, when the first solar array appeared on a rooftop in New York City. Experimentalist Charles Fritts installed it after discovering that a thin layer of selenium on a metal plate could produce a current of electricity when exposed to light. How light could turn on lights, he and his solar-pioneering contemporaries did not know, for the mechanics were not understood until the early twentieth century when, among other breakthroughs, Albert Einstein published his revolutionary work on what are now called photons. Though the scientific establishment of Fritts's day believed power generation depended on heat, Fritts was convinced that "photoelectric" modules would wind up competing with coal-fired power plants. The first such plant had been brought online by Thomas Edison just two years earlier, also in New York City.

Today, solar is replacing electricity generated from coal as well as from natural gas. It is replacing kerosene lamps and diesel generators in places where people lack access to the power grid, true for more than a billion people around the world. While society grapples with electricity's pollution in some places and its absence in others, the mysterious waves and particles of the sun's light continuously strike the surface of the planet with an energy more than ten thousand times the world's total use. Small-scale photovoltaic systems, typically sited on rooftops, are playing a significant role in harnessing that light, the most abundant resource on earth. When photons strike the thin wafers of silicon crystal within a vacuum-sealed solar panel, they knock electrons loose and produce an electrical circuit. These subatomic particles are the only moving parts in a solar panel, which requires no fuel.

While solar photovoltaics (PV) provide less than 2 percent of the world's electricity at present, PV has seen exponential growth over the past decade. In 2015 distributed systems of less than 100 kilowatts accounted for roughly 30 percent of solar PV capacity installed worldwide. In Germany, one of the world's solar leaders, the majority of photovoltaic capacity is on rooftops, which don 1.5 million systems. In Bangladesh, population 157 million, more than 3.6 million home solar systems have been installed. Fully 16 percent of Australian homes have them. Transforming a square meter of rooftop into a miniature power station is proving irresistible.

An Uros mother and her two daughters live on one of the 42 floating islands made of totora reeds on Lake Titicaca. Their delight upon receiving their first solar panel is infectious. Installed at an elevation of 12,507 feet, the panel will replace kerosene and provide electricity to her family for the first time. As high tech as solar may be, it is a perfect cultural match: The Uru People know themselves as Lupihaques, Sons of the Sun.

Roof modules are spreading around the world because of their affordability. Solar PV has benefited from a virtuous cycle of falling costs, driven by incentives to accelerate its development and implementation, economies of scale in manufacturing, advances in panel technology, and innovative approaches for end-user financing—such as the third-party ownership arrangements that have helped mainstream solar in the United States. As demand has grown and production has risen to meet it, prices have dropped; as prices have dropped, demand has grown further. A PV manufacturing boom in China has helped unleash a torrent of inexpensive panels around the world. But hard costs are only one side of the expense equation. The soft costs of financing, acquisition, permitting, and installation can be half the cost of a rooftop system and have not seen the same dip as panels themselves. That is part of the reason rooftop solar is more expensive than its utility-scale kin. Nonetheless, small-scale PV already generates electricity more cheaply than it can be brought from the grid in some parts of the United States, in many small island states, and in countries including Australia, Denmark, Germany, Italy, and Spain.

The advantages of rooftop solar extend far beyond price. While the production of PV panels, like any manufacturing process, involves emissions, they generate electricity without emitting greenhouse gases or air pollution—with the infinite resource of sunlight as their sole input. When placed on a grid-connected roof, they produce energy at the site of consumption, avoiding the inevitable losses of grid transmission. They can help utilities meet broader demand by feeding unused electricity into the grid, especially in summer, when solar is humming and electricity needs run high. This "net metering" arrangement, selling excess electricity back to the grid, can make solar panels financially feasible for homeowners, offsetting the electricity they buy at night or when the sun is not shining.

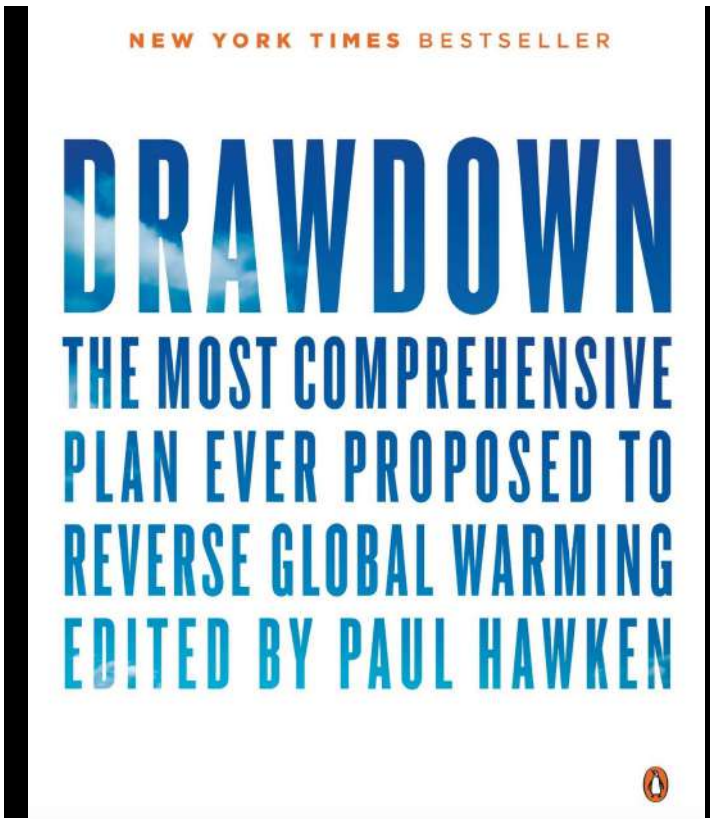
Numerous studies show that the financial benefit of rooftop PV runs both ways. By having it as part of an energy-generation portfolio, utilities can avoid the capital costs of additional coal or gas plants, for which their customers would otherwise have to pay, and broader society is spared the environmental and public health impacts. Added PV supply at times of highest electricity demand can also curb the use of expensive and polluting peak generators. Some utilities reject this proposition and posit contradictory claims of rooftop PV being a "free rider," as they aim to block the rise of distributed solar and its impact on their revenue and profitability. Others accept its inevitability and are trying to shift their business models accordingly. For all involved, the need for a grid "commons" continues, so utilities, regulators, and stakeholders of all stripes are evolving approaches to cover that cost.

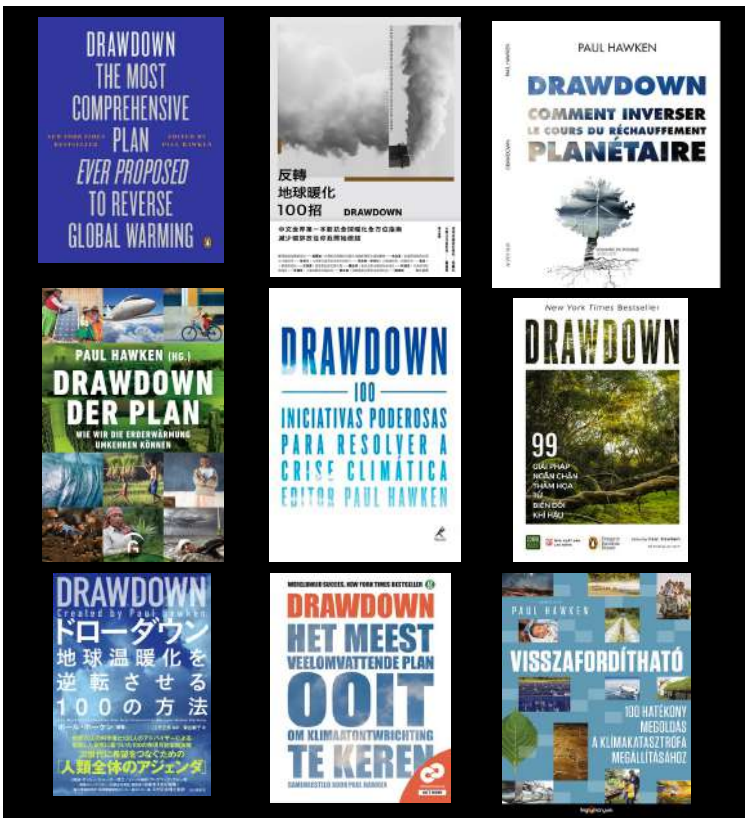
The first solar array installed by Charles Fritts in 1884 in New York City. Fritts built the first solar panels in 1881, reporting that the current was "continuous, constant, and of considerable force not only by exposure to sunlight but also to dim, diffused daylight, and even to lamplight."

Off the grid, rooftop panels can bring electricity to rural parts of low-income countries. Just as mobile phones leapfrogged installation of landlines and made communication more democratic, solar systems eliminate the need for large-scale, centralized power grids. High-income countries dominated investment in distributed solar until 2014, but now countries such as Chile, China, India, and South Africa have joined in. It means rooftop PV is accelerating access to affordable, clean electricity and thereby becoming a powerful tool for eliminating poverty. It is also creating jobs and energizing local economies. In Bangladesh alone, those 3.6 million home solar systems have generated 115,000 direct jobs and 50,000 more downstream.

Since the late nineteenth century, human beings in many places have relied on centralized plants that burn fossil fuels and send electricity out to a system of cables, towers, and poles. As households adopt rooftop solar (increasingly accompanied and enabled by distributed energy storage), they transform generation and its ownership, shifting away from utility monopolies and making power production their own. As electric vehicles also spread, "gassing up" can be done at home, supplanting oil companies. With producer and user as one, energy gets democratized. Charles Fritts had this vision in the 1880s, as he looked out over the rooftscape of New York City. Today, that vision is increasingly coming to fruition. ❋

IMPACT: *Our analysis assumes rooftop solar PV can grow from 4 percent of electricity generation globally to 7 percent by 2050. That growth can avoid 24.6 gigatons of emissions. We assume an implementation cost of $1,885 per kilowatt, dropping to $622 per kilowatt by 2050. Over three decades, the technology could save $3.4 trillion in home energy costs.*





DRAWDOWN 2020

THE LATEST CLIMATE SOLUTIONS RESEARCH + INSIGHTS

THE DRAWDOWN-ALIGNED BUSINESS FRAMEWORK

EMISSIONS REDUCTIONS

- Accelerate goals, include interim targets, and phase out use of offsets
- Use carbon removal technology as a last resort and only for unavoidable emissions
- Address supply chain and historical emissions
- Institutionalize emissions reduction efforts
- Embed climate justice

CLIMATE DISCLOSURES

- Publicly disclose climate-related risk and support mandatory disclosure standards

STAKEHOLDER ENGAGEMENT AND COLLABORATION

- Engage employees on climate action
- Create pathways for every job to be a climate job
- Ensure the board is climate-competent
- Engage and support local communities

CLIMATE POLICY ADVOCACY

- Use influence to advocate for climate policy at all levels of government
- Align political contributions
- Focus lobbying dollars on just climate solutions
- Push trade associations to align

PRODUCTS, PARTNERSHIPS, AND PROCUREMENT

- Ensure products and partnerships don't serve bad climate actors
- Require suppliers to adopt science-based emissions reductions targets
- Prioritize circularity and low carbon materials

BUSINESS MODEL TRANSFORMATION

- Embed climate considerations into every part of the business
- Focus business model on scaling climate solutions, phase out parts of the business that are incompatible

INVESTMENTS AND FINANCING

- Offer employees climate-friendly retirement plans and investment opportunities
- Push banks and asset managers to align investments with the Paris Agreement
- Pressure insurance companies to stop underwriting and investing in carbon-intensive projects

LONG-TERM THINKING

- Value long-term thinking over short-term profit and prioritize building a just climate future for all

PROJECT DRAWDOWN

How to Accelerate Climate Solutions

SHAPE CULTURE.

SHIFT CAPITAL.

BUILD POWER.

CHANGE BEHAVIOR.

SET GOALS.

ALTER RULES & POLICY.

IMPROVE TECHNOLOGY.

How to Accelerate Climate Solutions

Shape Culture

Culture is a critical context for climate solutions and action, telling us what's right or wrong, what's possible or impossible. **Stories, the arts, dialogue, and visioning are some of the means of (re)shaping culture and collective beliefs about how the world works or could**. Cultural change can feel diffuse, but it sets the context for what we do as a society and can foster a sense of collective courage.

Build Power

Power is a precondition for creating change. In the past, too much power has been deployed against climate action; too little has been assembled to advance solutions. We build power by building community, movements, and diverse leadership. **When the concentrated power and entrenched interests of industry or government work against transformation, people power offers a corrective.**

Set Goals

Goals govern direction. What are we reaching for, and why? On climate but also more broadly, goals can be specific and numeric (e.g., "carbon neutral by 2050"), or they can be higher-order, more systemic ambitions (e.g., "a climate-just future"). **Sometimes, a new goal can dramatically shift where we're headed—and the solutions and approaches we bring to bear.**

How to Accelerate Climate Solutions

Alter Rules & Policy

Rules create boundaries. They tell us what is desirable and perhaps encouraged, or what is unwanted and perhaps punished. Laws, regulations, standards, taxes, subsidies, and incentives are means of changing the state of play on climate, but hinge on who writes the rules. **Policy shifts can advance solutions while stopping sources of the problem.**

Shift Capital

Given our economic system, money is necessary fuel for making change. **Public and private investment and philanthropic giving can stimulate and sustain climate solutions and efforts to move them forward**. **Divestment is also powerful**, shifting capital away from the sources of the problem, essentially restricting their blood flow.

How to Accelerate Climate Solutions

Change Behavior

From individuals to corporations and beyond, behavior is what's done and how. All climate solutions have behavioral dimensions, and some hinge almost entirely on human habit. Knowledge, norms, criteria, and motivations can shift behavior and create new ways of operating. **Where changes in behavior aggregate, outcomes can shift significantly.**

Improve Technology

To stop the sources of emissions, technology must evolve. "Now is better than new" when it comes to climate solutions, but through innovation, research, and development, technology may continue to improve and add to the solutions at hand. This is especially critical for the most intractable sectors, such as heavy industry and aviation.


CLIMATE ACTION CHECKLIST FOR CORPORATE FINANCE PROFESSIONALS
DO YOU WORK IN CORPORATE FINANCE?
GOOD NEWS:
YOUR JOB IS A CLIMATE JOB
Read through this checklist and pick one or more actions to pursue. (Bonus: Work your way through all of them!)
BANKING
Direct decision-makers toward banks that are: 1) minimally financing the fossil fuel industry and deforestation; 2) shifting their financing to climate solutions; 3) committing to aggressive anti-fossil fuel policies; and 4) calculating their financed emissions.
LENDING
Gather colleagues to express concern to your bank over its fossil fuel lending and lack of transition plan.
INSURANCE
If your company works with an insurance broker, inform them that you want to consider not only policies and pricing but also the sustainability of insurance carriers during each insurance renewal.
BORROWERS AND SUPPLIERS
Offer your company's borrowers and suppliers better terms and rates when they reach sustainability milestones you set and encourage them to achieve.
CASH
Encourage decision-makers to allocate excess cash to banks that are fossil fuel-free, B Corp, or members of the Global Alliance for Banking on Values (GABV). While large, established banks may be needed for many of your company's financial services, lower-impact services and excess cash can be held with value-aligned banks.
INVESTMENTS
Invest in products, strategies, and businesses that align with climate solutions.
TRAVEL
Minimize carbon-intensive business travel and opt for virtual gatherings. If possible, instead of flying, choose lower-carbon options such as the train.
EMPLOYEE RETIREMENT BENEFITS
Team up with the human resources and operations team to evaluate whether 401(k)s, retirement plans, and other portfolios are invested in fossil fuels. If they are, work to shift the default retirement option to a climate-safe one (or, at minimum, offer climate-friendly funds in their place).
DIALOGUE AND ACTION
Brainstorm action with colleagues on your team and beyond. Raise your collective concern at team and all-staff meetings.
From Drawdown Labs, a program of
PROJECT DRAWDOWN


GOVERNMENT RELATIONS & PUBLIC POLICY
HUMAN RESOURCES & OPERATIONS
LEGAL
MARKETING
PROCUREMENT
SALES & CLIENT-FACING ROLES


DO YOU WORK IN GOVERNMENT RELATIONS OR PUBLIC POLICY? GOOD NEWS:
YOUR JOB IS A CLIMATE JOB


DO YOU WORK IN HUMAN RESOURCES OR OPERATIONS? GOOD NEWS:
YOUR JOB IS A CLIMATE JOB


DO YOU WORK AS AN IN-HOUSE LEGAL PROFESSIONAL? GOOD NEWS:
YOUR JOB IS A CLIMATE JOB


DO YOU WORK IN MARKETING? GOOD NEWS:
YOUR JOB IS A CLIMATE JOB


BUILDING A REGENERATIVE FUTURE

Exploring climate change drivers and solutions in multiple sectors.

17th March 2025,
Fundamentals on Environment and Sustainability, NOVA SBE

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