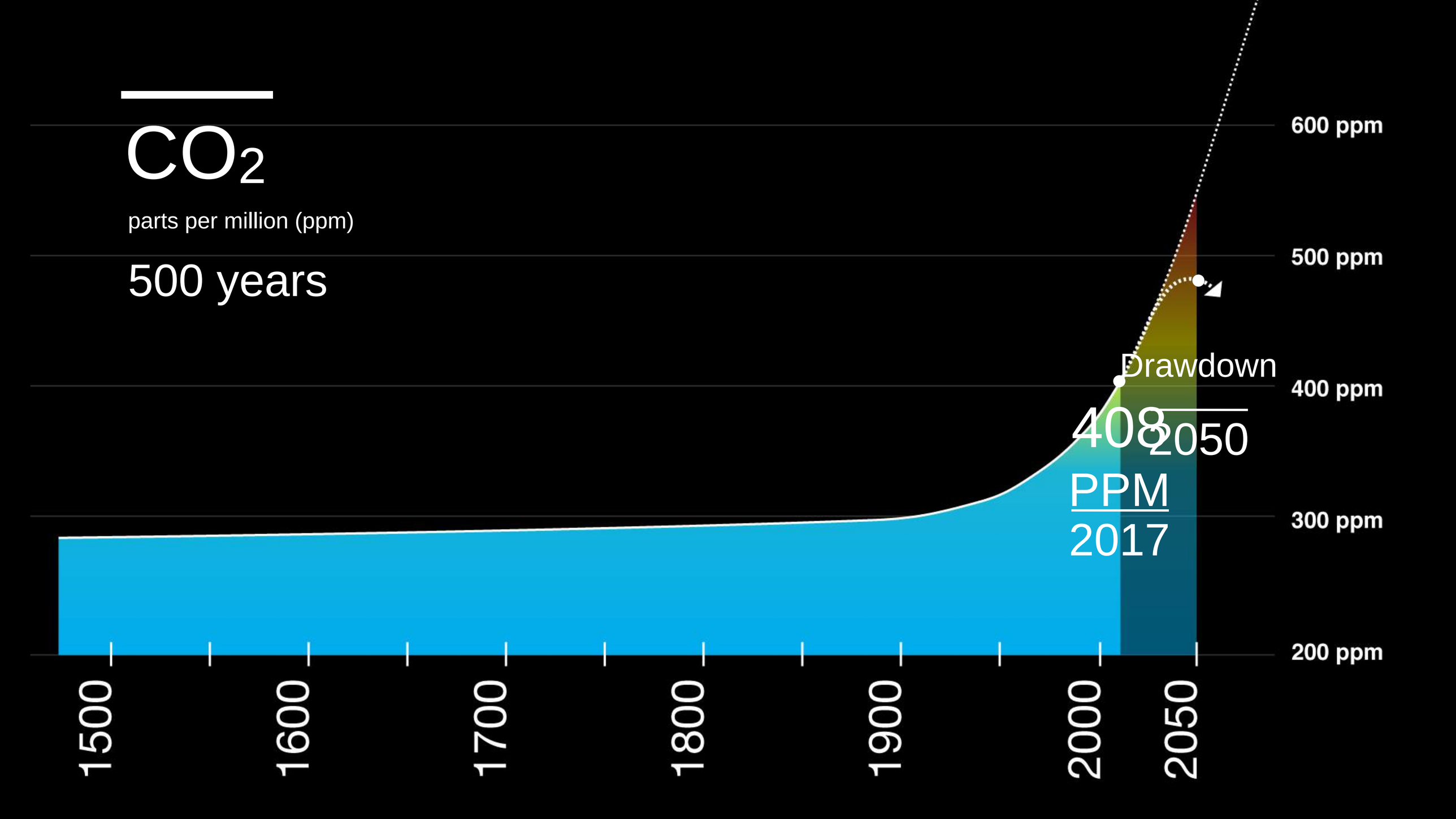
DRAWDOWN

João Pedro Gouveia, PhD

Seminário Eco-Escolas, 17 Janeiro 2018


CO_2
parts per million (ppm)
400,000 years
For centuries, atmospheric carbon dioxide had never been above this line
current level
1950 level
450 ppm
375 ppm
300 ppm
225 ppm
150 ppm
400,000
300,000
200,000
100,000
0
years
before today
(0 = 1950)


$\overline{CO_2}$
parts per million (ppm)
500 years
600 ppm
500 ppm
400 ppm
300 ppm
200 ppm
Drawdown
408 ppm
2017
2050
1500
1600
1700
1800
1900
2000
2050

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.

DRAWDOWN

Language

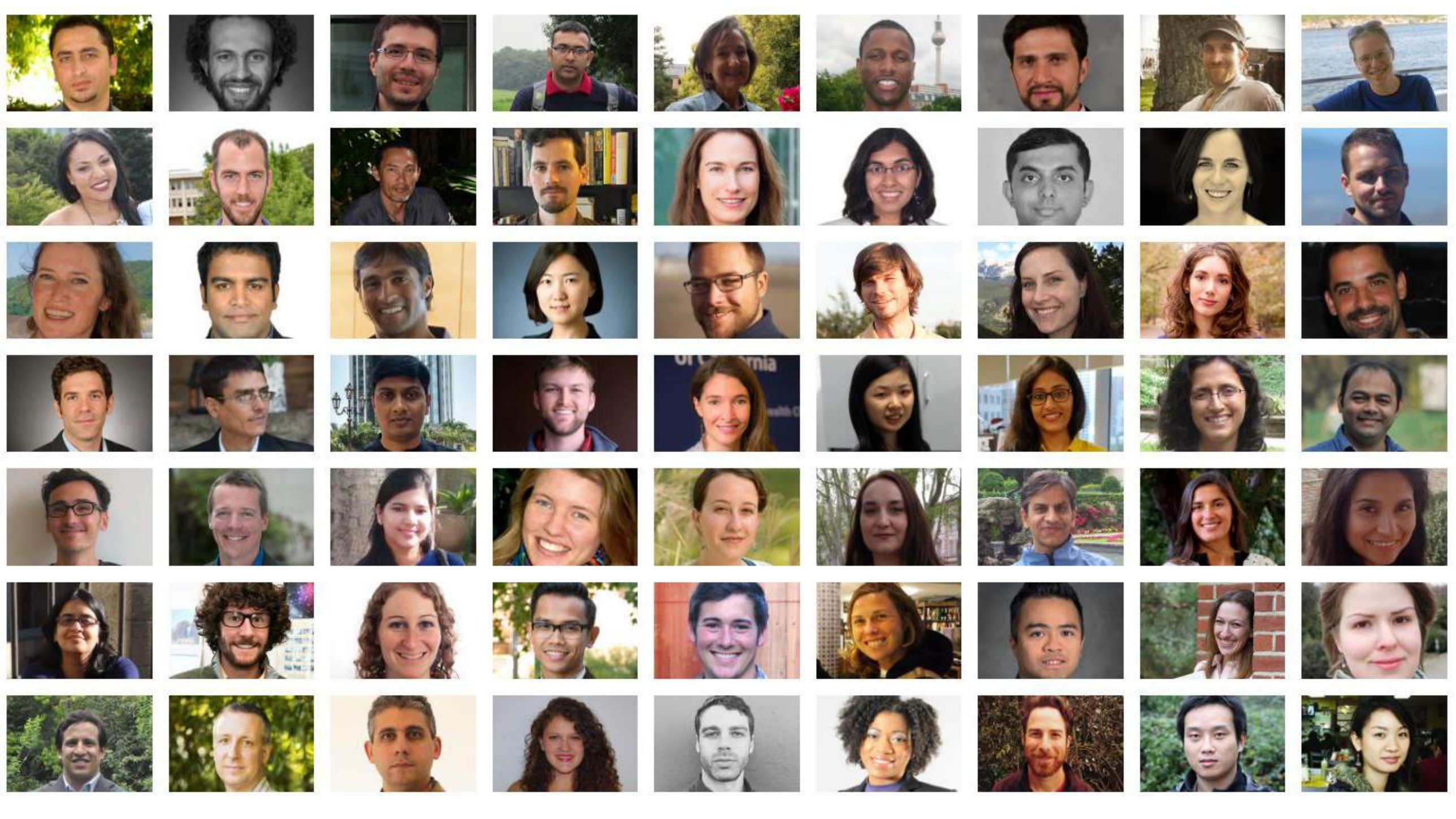
- Climate science contains its own vocabulary, acronyms, lingo and jargon. It is a language derived by scientists and policy makers that is succinct, specific and useful.

- However as means of communication to the broader public, it can create separation and distance.

- We have sought to make Drawdown understandable for people from all backgrounds and points of view.

- We endeavored to bridge the climate communication gap by the words we choose and the jargon we stay away from.

The Coalition



Project Drawdown maps and models solutions

Research Aim & General Approach

Drawdown is the only sensible goal for humanity

- Is drawdown possible? And financially feasible?
- Top-down, sectoral models were not comprehensive or empowering
- The Drawdown Models can be applied to any technology or practice, at global scale
- Collaborative research from Drawdown Fellows across the globe

What is a “solution”?

To collect, analyze, and present the best available information and data on solutions that:

1. **REDUCE** through efficiency and resource productivity;
2. **REPLACE** existing energy sources with renewable energy
3. **RESTORE** carbon in our soils and plants by bio-sequestering CO_2

The Solutions

80 Solutions already exist

Criteria for inclusion:

1. *Existing and scaling*
2. *Economically viable*
3. *Reduction potential*
4. *No regrets (with some exceptions)*
5. *Availability of data*

20 Coming Attractions

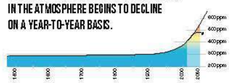
DRAWDOWN

100 SOLUTIONS TO REVERSE GLOBAL WARMING BY 2050

RANKED BY IMPACT

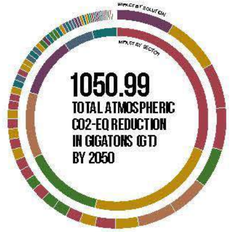
drawdown.org

DRAWDOWN IS THAT POINT IN TIME WHEN THE CONCENTRATION OF GREENHOUSE GASES IN THE ATMOSPHERE BEGINS TO DECLINE ON A YEAR-TO-YEAR BASIS.



Project Drawdown is the most comprehensive plan ever proposed to reverse global warming. Our organization did not make or devise the plan—we found the plan because it already exists. We gathered a qualified and diverse group of researchers from around the world to identify, research, and model the 100 most substantive, existing solutions to address climate change. What was uncovered is a path forward that can roll back global warming within thirty years. It shows that humanity has the means at hand. Our work is to accelerate the knowledge and growth of what is possible. We chose the name Drawdown because if we do not name the goal, we are unlikely to achieve it.

EACH SOLUTION REDUCES GREENHOUSE GASES BY AVOIDING EMISSIONS AND/OR BY SEQUESTERING CARBON DIOXIDE ALREADY IN THE ATMOSPHERE.

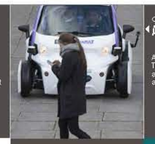


Land Use
AFFORESTATION
Afforestation—creating forests where there were none before—creates a carbon sink, drawing in and holding on to carbon and distributing it into the soil.
18.06 GT REDUCED CO2 #15

Transport
AIRPLANES
The airline industry produces at minimum 2.5 percent of emissions, and it is growing. Fuel efficiency measures are on the rise to reduce that impact.
5.05 GT REDUCED CO2 #43

Materials
ALTERNATIVE CEMENT
Cement, a vital material for infrastructure, generates 5 to 6 percent of annual emissions. The key strategy to reduce them is to change its composition.
6.69 GT REDUCED CO2 #36

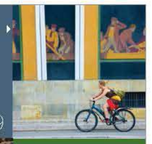
Coming Attractions
ARTIFICIAL LEAF
The artificial leaf is technology inspired by photosynthesis. It combines solar energy, water, and carbon dioxide, to feed bacteria that synthesize energy-dense fuel.



Coming Attractions
AUTONOMOUS VEHICLES
Autonomous vehicles are on the rise. They have the potential to shrink the auto fleet and accelerate ridesharing and the adoption of electric vehicles.

Land Use
BAMBOO
Bamboo rapidly sequesters carbon in biomass and soil, and can thrive on degraded lands. It has more than 1,000 uses, from buildings to food to paper.
7.22 GT REDUCED CO2 #35

Buildings and Cities
BIKE INFRASTRUCTURE
2.31 GT REDUCED CO2 #59



Food
BIOCHAR
Biochar results from slowly baking biomass in the absence of oxygen, fostering most of the feedstock's carbon. Biochar can be buried for sequestration, while enriching soil.
0.81 GT REDUCED CO2 #72

Materials
BIOPLASTIC
Ninety percent of plastics could be derived from plants instead of fossil fuels. Bio-plastics can be biodegradable and often have lower emissions.
4.30 GT REDUCED CO2 #47

Buildings and Cities
BUILDING AUTOMATION
Building automation systems sense as the "brain" of large commercial buildings. Controlling temperature, lighting, and more, they can improve energy efficiency and occupants' comfort.
4.62 GT REDUCED CO2 #45

Coming Attractions
BUILDING WITH WOOD
High-performance wood materials are transforming construction. They can reduce emissions by (1) sequestering and storing carbon and (2) avoiding emissions of cement and steel.

Transport
CARS
Hybrid cars pair an electric motor and battery with an internal combustion engine. The combination makes them more efficient, improving fuel economy and lowering emissions.
4.00 GT REDUCED CO2 #49

Food
CLEAN COOKSTOVES
Traditional cooking practices produce toxic smoke and 2 to 5 percent of annual greenhouse gas emissions. Clean cookstoves reduce emissions and protect human health.
15.61 GT REDUCED CO2 #21

Land Use
COASTAL WETLAND
The world's salt marshes, mangroves, and sea grasses provide vital habitat, flood protection, and water filtration, and sequester huge amounts of carbon in plants and soil.
3.19 GT REDUCED CO2 #52

Energy
COGENERATION
Power plants produce large amounts of waste heat. Cogeneration systems capture that thermal energy and put it to work—for district heating or additional electricity.
3.97 GT REDUCED CO2 #50

Food
COMPOSTING
From backyard bins to industrial-scale operations, composting food waste converts organic material into stable soil carbon and valuable fertilizer, averting methane emissions.
2.28 GT REDUCED CO2 #60

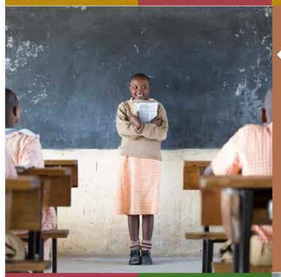
Energy
CONCENTRATED SOLAR
Concentrated solar power uses solar radiation as its primary fuel. Arrays of mirrors concentrate incoming rays to heat a fluid, produce steam, and turn turbines.
10.90 GT REDUCED CO2 #25

Food
CONSERVATION AGRICULTURE
Conservation agriculture avoids tilling and employs cover crops and crop rotation. By protecting the soil, it makes land more resilient and sequesters carbon.
17.35 GT REDUCED CO2 #16

Coming Attractions
DIRECT AIR CAPTURE
Direct Air Capture systems are a nascent sequestration technology. Functioning like a chemical sieve and sponge, they capture carbon dioxide from air and release it in purified form.

Coming Attractions
A COW WALKS ONTO A BEACH
Asparagopsis taxiformis, a species of seaweed, shows promise for reducing methane emissions from livestock—currently 4 to 5 percent of annual greenhouse gas emissions.

Buildings and Cities
DISTRICT HEATING
With district systems, a central plant channels hot and/or cool water via a network of pipes to many buildings—heating and cooling them more efficiently.
9.36 GT REDUCED CO2 #27



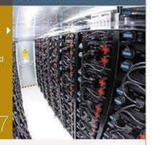
Women and Girls
EDUCATING GIRLS
Education lays a foundation for vibrant lives for girls and women, their families, and their communities. It also avoids emissions by curbing population growth.
59.60 GT REDUCED CO2 #6

Transport
ELECTRIC BIKES
Electric bikes get a boost from a small battery-powered motor. They are the most environmentally sound means of motorized transport in the world today.
0.96 GT REDUCED CO2 #69

Transport
ELECTRIC VEHICLES
Electric vehicles are the cars of the future. If powered by solar energy, their carbon dioxide emissions drop by 95 percent compared to gasoline-powered vehicles.
10.80 GT REDUCED CO2 #26

Energy
ENERGY STORAGE (DISTRIBUTED)
Standalone batteries and electric vehicles make it possible to store energy at home or work. They ensure supply even when variable renewables are not producing.
AN ENABLING TECHNOLOGY. COST AND SAVINGS ARE EMBEDDED IN RENEWABLE ENERGY
#77

Energy
ENERGY STORAGE (UTILITIES)
Energy storage—daily, multiday, and longer-term or seasonal—is vital to reduce emissions from polluting "peaker" plants and accommodate the shift to variable renewables.
AN ENABLING TECHNOLOGY. COST AND SAVINGS ARE EMBEDDED IN RENEWABLE ENERGY
#77



Coming Attractions
ENHANCED WEATHERING OF MINERALS
Natural weathering of silicate rock sequesters carbon dioxide. Enhanced weathering aims to hasten that process by milling rock powder and applying it to landscapes.

Women and Girls
FAMILY PLANNING
Securing women's right to voluntary, high-quality family planning dramatically improves the health and well-being of women and their children. It also avoids emissions.
59.60 GT REDUCED CO2 #7

Food
FARMLAND IRRIGATION
Pumping and distributing water requires large quantities of energy. Drip and sprinkler irrigation, among other practices and technologies, make water use more precise and efficient.
1.33 GT REDUCED CO2 #67

Food
FARMLAND RESTORATION
The world's abandoned farmland is an opportunity for drawdown. Restoring it sequesters carbon and can improve food security, farmers' livelihoods, and ecosystem health.
14.08 GT REDUCED CO2 #23

Land Use
FOREST PROTECTION
With mature canopy trees and complex understories, primary forests contain 300 billion tons of carbon and are the greatest repositories of biodiversity on the planet.
6.20 GT REDUCED CO2 #38

Energy
GEOTHERMAL
Geothermal power—literally "earth heat"—taps into underground reservoirs of steam or hot water, which can be piped to the surface to drive turbines that produce electricity.
16.60 GT REDUCED CO2 #18

Buildings and Cities
GREEN ROOFS
Green roofs use soil and vegetation as living insulation. Cool roofs reflect solar energy. Both reduce building energy use for heating and/or cooling.
0.77 GT REDUCED CO2 #73

Energy
GRID FLEXIBILITY
For electricity supply to become predominantly or entirely renewable, the grid needs to become more flexible and adaptable than it is today.
AN ENABLING TECHNOLOGY. COST AND SAVINGS ARE EMBEDDED IN RENEWABLE ENERGY
#77

Buildings and Cities
HEAT PUMPS
Heat pumps transfers heat from a cold space to a hot one. Highly efficient, they can dramatically lower building energy use for heating and cooling.
5.20 GT REDUCED CO2 #42

Transport
HIGH-SPEED RAIL
High-speed rail is the fastest way to travel distances between 100 to 700 miles. Compared to driving or flying, it reduces emissions up to 90 percent.
1.52 GT REDUCED CO2 #66

Materials
HOUSEHOLD RECYCLING
Household recycling can reduce emissions because producing new products from recovered materials often saves energy. It also reduces resource extraction and creates jobs.
2.77 GT REDUCED CO2 #55

Coming Attractions
HYDROGEN-BORON FUSION
Tri Alpha Energy has achieved one-half of the nuclear fusion equation. It could herald clean, safe, affordable energy to take the world beyond fossil fuels.

Coming Attractions
HYPERLOOP
The promise of Hyperloop is speed. The virtue is removing people and cargo with 90 to 95 percent less energy than planes, trains, or cars.

Food
IMPROVED RICE CULTIVATION
Flooded rice paddies produce large quantities of methane—10 percent of agricultural emissions. Techniques exist to reduce methane, while improving production and sequestering carbon.
11.34 GT REDUCED CO2 #24

Energy
IN-STREAM HYDRO
Placed within a free-flowing river or stream, in-stream turbines capture water's energy without a dam. In remote communities, they can replace expensive, dirty diesel generators.
4.00 GT REDUCED CO2 #48

Land Use
INDIGENOUS PEOPLES' LAND MANAGEMENT
Growing the acreage under secure indigenous land tenure can increase forest- and tallgrass-soil carbon stocks and reduce greenhouse gas emissions from deforestation.
6.19 GT REDUCED CO2 #39

Coming Attractions
INDUSTRIAL HEMP
Hemp is a global warming solution primarily because of what it can replace: cotton. Cotton has high chemical use and depends on fossil fuel inputs.

Materials
INDUSTRIAL RECYCLING
Industrial recycling reduces emissions when new products are made from recovered materials, rather than virgin resources. It can also address the challenge of resource scarcity.
2.77 GT REDUCED CO2 #56

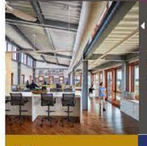
Buildings and Cities
INSULATION
Insulation is one of the most cost-effective ways to make buildings more energy efficient—both in new construction and through retrofitting older buildings.
8.27 GT REDUCED CO2 #31

Coming Attractions
INTENSIVE SILVOPASTURE
Intensive silvopasture intercrops a leguminous woody shrub with grasses and trees. Through rapid rotational grazing, livestock yields increase alongside carbon sequestration in soil.

Buildings and Cities
LANDFILL METHANE
Landfills are a top source of methane emissions. Instead, landfill methane can be captured, preventing emissions, and used as a fairly clean energy source.
2.50 GT REDUCED CO2 #58

Buildings and Cities
LED LIGHTING (COMMERCIAL)
Lighting accounts for 15 percent of global electricity use. LEDs (light emitting diodes) require less energy and create less waste heat than other bulbs.
5.04 GT REDUCED CO2 #44

Buildings and Cities
LED LIGHTING (HOUSEHOLD)
By transitioning most of their energy use into creating light—rather than heat, like older technologies—LEDs reduce electricity consumption and air-conditioning loads.
7.61 GT REDUCED CO2 #33



Coming Attractions
LIVING BUILDINGS
The Living Building Challenge holistically defines how buildings can benefit both people and planet. One key criteria: Living buildings produce more energy than they use.

Food
MANAGED GRAZING
Managed grazing imitates the activity of migratory herds to improve soil health, carbon sequestration, water retention, and forage productivity.
16.34 GT REDUCED CO2 #19

Coming Attractions
MARINE PERMACULTURE
Marine permaculture utilizes floating, latticed structures designed to grow rich kelp forests and foster marine life. It could sequester billions of tons of carbon dioxide.

Transport
MASS TRANSIT
Riding a streetcar, bus, or subway—rather than driving a car or hailing a cab—diverts greenhouse gases, relieves traffic congestion, and reduces air pollution.
6.57 GT REDUCED CO2 #37

Energy
METHANE DIGESTERS (LARGE)
Industrial-scale anaerobic digesters control decomposition of organic waste, and thus its methane emissions. They also produce biogas, an energy source, and digestate, a nutrient-rich fertilizer.
8.40 GT REDUCED CO2 #30

Energy
METHANE DIGESTERS (SMALL)
At backyard- and farm yard-scale, anaerobic digesters are used to manage organic waste. They control methane emissions, while producing biogas (an energy source) and digestate (nutrient-rich fertilizer).
1.90 GT REDUCED CO2 #64

Energy
MICRO WIND
With capacity of 100 kilowatts or less, micro wind turbines are often used to pump water, charge batteries, and provide electrification in rural locations.
0.20 GT REDUCED CO2 #76

Coming Attractions
MICROBIAL FARMING
Microbes have the potential to dramatically reduce the need for synthetic fertilizers, pesticides, and herbicides, while improving crop yields and plant health.

Energy
MICROGRIDS
A microgrid is a localized grouping of distributed energy sources, like solar and wind, together with energy storage or backup generation and load management tools.
AN ENABLING TECHNOLOGY. COST AND SAVINGS ARE EMBEDDED IN RENEWABLE ENERGY
#78

Food
MULTISTRATA AGROFORESTRY
Multistrata agroforestry blends taller trees and one or more layers of crops. It achieves high rates of carbon sequestration, similar to forests, while producing food.
9.26 GT REDUCED CO2 #28

Buildings and Cities
NET ZERO BUILDINGS
A net zero building is one that has zero net energy consumption, producing as much energy, through onsite renewables, as it uses in a year.
COST AND SAVINGS MODELED IN RENEWABLE ENERGY AND OTHER TECHNOLOGIES
#79

Energy
NUCLEAR
Nuclear power is complex, expensive, and risk-but it has the potential to avoid emissions from fossil fuel electricity. We consider it a "regrets solution."
16.09 GT REDUCED CO2 #20

Food
NUTRIENT MANAGEMENT
When overused, nitrogen fertilizers destroy soil organic matter, pollute waterways, and create nitrous oxide. They can be more efficiently managed to reduce these negative impacts.
1.81 GT REDUCED CO2 #65

Coming Attractions
OCEAN FARMING
Small-scale ocean farms have the potential to provide sustainable food and biofuel, while oysters filter nitrogen pollution and seaweeds sequesters carbon dioxide.

Poster (upper half) presenting Drawdown solutions all on one sheet—a 'periodic table' of climate solutions.

The Scenarios

Will compare a **reference scenario** that assumes current adoption of Solution remain constant (2020-2050).

~ with ~

an **high adoption scenario** assuming a reasonably vigorous global adoption path (2020-2050).

Three **high adoption scenarios** were developed:

1. Plausible Scenario
2. Drawdown Scenario
3. Optimum Scenario

The Results

NEW YORK TIMES BESTSELLER

DRAWDOWN

THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING

EDITED BY PAUL HAWKEN

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NEW YORK TIMES BESTSELLER

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DRAWDOWN

Nous savons qu'il nous reste peu de temps pour agir. Un nombre toujours plus important de scientifiques nous mettent en garde : dans quelques années, il sera trop tard. Le changement climatique menace de défaire le tissu social, de saper les fondations mêmes de la démocratie et de précipiter la disparition de nombreuses espèces. Dont l'être humain.

Fort de cette urgence, *Drawdown* propose une feuille de route à l'usage des gouvernements, des territoires, des villes, des entreprises et de chacun d'entre nous. Plutôt que de baisser les bras, ce livre veut nous aider à surmonter la peur, la confusion et l'apathie, pour passer à l'acte.

Drawdown désigne le point de bascule à partir duquel la concentration de gaz à effet de serre dans l'atmosphère, après avoir atteint un pic, se met à diminuer d'une année sur l'autre.

L'objectif de ce livre est de nous aider à engager cette bascule.

Pour y parvenir, Paul Hawken et soixante-dix chercheurs ont élaboré un plan inédit : quatre-vingts solutions pour inverser le cours du changement climatique. En décrivant leurs impacts positifs sur le monde financier, les relations sociales et l'environnement, ils nous enjoignent à organiser notre action : commencer par ce qui aura le plus d'impact et construire une stratégie globale.

Nous disposons de tous les outils nécessaires, à nous de nous mettre au travail.

Né le 8 février 1946, Paul Hawken est un des écologistes les plus respectés aux États-Unis et un spécialiste du climat. Il est l'auteur de nombreux ouvrages parmi lesquels Blessed Unrest, The Ecology of Commerce *ou* The Next Economy. *Il vit à San Francisco.*

Traduit de l'anglais (États-Unis) par Amanda Prat-Giral

Dessin de couverture : © David Delfos, 2011

ACTES SUD
DÉP. LÉG. : MAI 2018
XX € TTC France
www.actes-sud.fr

ISBN 978-2-330-09613-7

PAUL HAWKEN

DRAWDOWN

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COMMENT INVERSER LE COURS DU RÉCHAUFFEMENT PLANÉTAIRE

DRAWDOWN

100 INICIATIVAS PODEROSAS PARA RESOLVER A CRISE CLIMÁTICA

EDITOR PAUL HAWKEN

Manole

AS 100 SOLUÇÕES MAIS IMPORTANTES PARA REVERTER O AQUECIMENTO GLOBAL, FUNDAMENTADAS EM PESQUISAS CONDUZIDAS POR CIENTISTAS DE PONTA E FORMULADORES DE POLÍTICAS DE TODAS AS PARTES DO MUNDO.

"Consideramos o aquecimento global não como um fato inevitável, mas como um convite para construir, inovar e efetuar mudanças, um caminho que desperta a nossa criatividade, compaixão e inventividade." — Paul Hawken, diretor executivo do Projeto *Drawdown*

"Este livro deve ser adotado como o plano para a construção de um mundo climaticamente seguro. Mediante a modelagem de soluções práticas, de fácil entendimento e que já estão ganhando escala, *Drawdown* aponta para um futuro no qual poderemos reverter o aquecimento global e deixar um mundo melhor como herança para as futuras gerações." — Jonathan Foley, diretor executivo da California Academy of Science

"*Drawdown* é a mais completa lista de remédios para a saúde planetária e para o bem-estar da humanidade no presente e no futuro. Deverá ser um grande catalisador – ao unir o desejo majoritário da humanidade de legar um futuro decente e sustentável para as futuras gerações." — Carlos A. Nobre, pesquisador aposentado do INPE e membro da Academia Brasileira de Ciências

"Nós somos os agentes dessa transformação, e o *Drawdown* é o primeiro passo para começarmos a regenerar as nossas relações com o planeta, com os outros e com nós mesmos." — Pedro Paulo Diniz, membro do Conselho do Projeto *Drawdown*

"Essa mudança precisa acontecer. Nossa saúde, nossa existência e nosso futuro dependem da saúde do nosso planeta... É essencial honrar a natureza, pois somente assim começaremos a honrar a nós mesmos, reconectando-nos com quem somos." — Gisele Bündchen, ativista de causas socioambientais

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Manole


WERELDWIJD SUCCES, NEW YORK TIMES BESTSELLER
DRAWDOWN
HET MEEST
VEELOMVATTENDE PLAN
OOIT
OM KLIMAATONTWRICHTING
TE KEREN
SAMENGESTELD DOOR PAUL HAWKEN
ACT NOW

ENERGY

ROOFTOP SOLAR

RANKING AND RESULTS BY 2050 #10

24.6 GIGATONS REDUCED CO_2	$453.1 BILLION NET COST	$3.46 TRILLION 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.

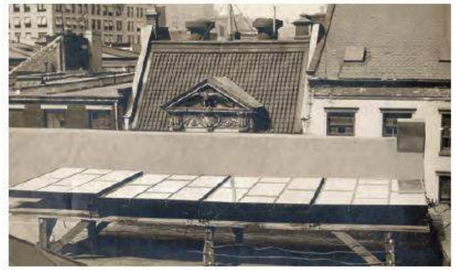
While solar photovoltaics (PV) provide less than 2 percent of the world's electricity at present, PV has seen exponential growth over the past decade. In 2015 distributed systems of less than 100 kilowatts accounted for roughly 30 percent of solar PV capacity installed worldwide. In Germany, one of the 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.



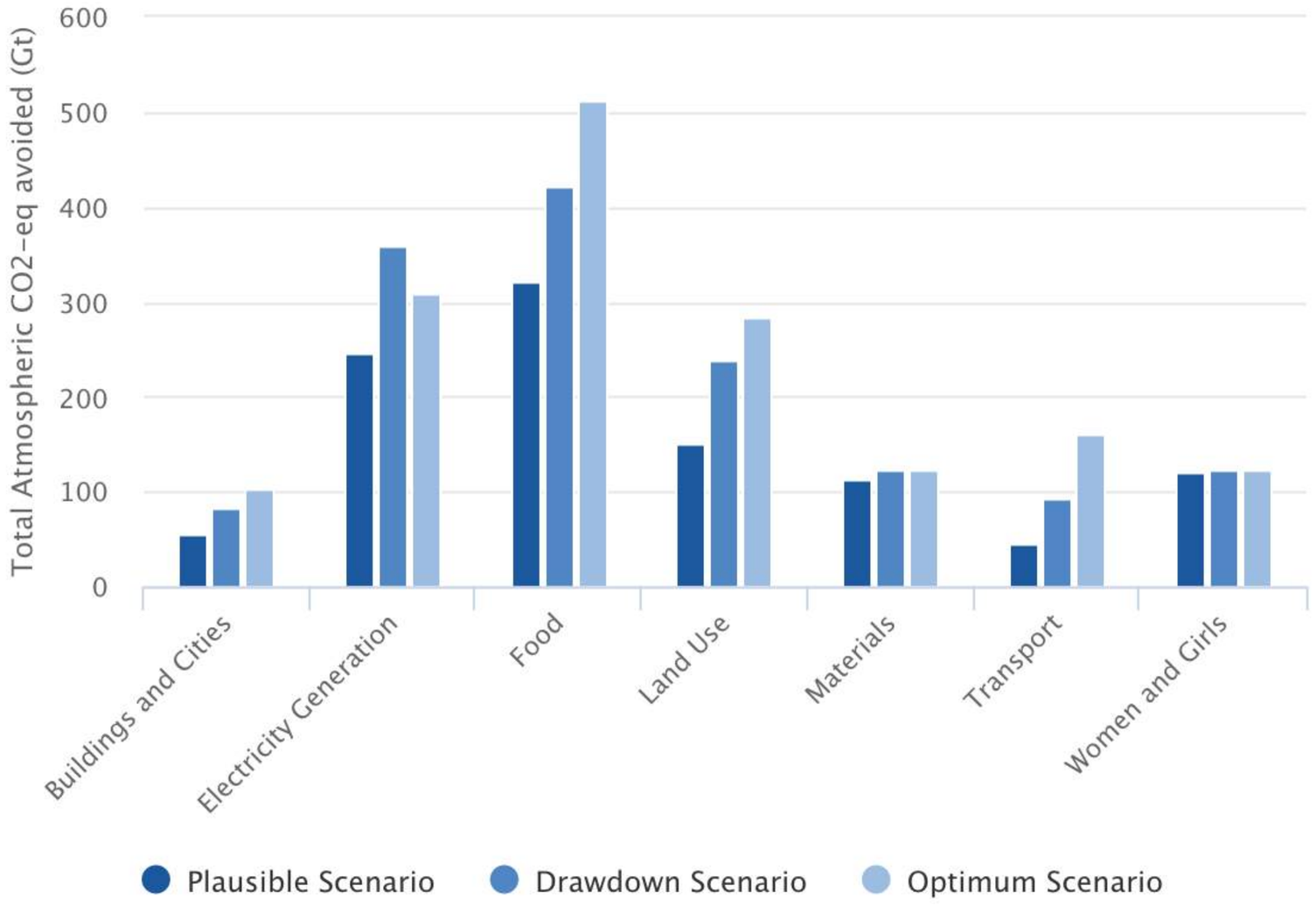
The first solar array installed by Charles Fritts in 1884 in New York City. Fritts built the first solar panels in 1881, reporting that the current was "continuous, constant and of considerable force not only by exposure to sunlight but also to dim, diffused daylight, and even to lamplight."

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 roofscape 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 $1,883 per kilowatt, dropping to $627 per kilowatt by 2050. Over three decades, the technology could save $3.4 trillion in home energy costs.*

Results Impact (2020-2050)



TOP 20

Plausible Scenario

RANK	SOLUTION	SECTOR	REDUCED CO2
1	**Refrigeration**	Materials	89.74 GT
2	**Wind Turbines (Onshore)**	Electricity generation	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	59.60 GT
7	**Family Planning**	Women and Girls	59.60 GT
8	**Solar Farms**	Electricity generation	36.90 GT
9	**Silvopasture**	Food	31.19 GT
10	**Rooftop Solar**	Electricity generation	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 generation	16.60 GT
19	**Managed Grazing**	Food	16.34 GT
20	**Nuclear**	Electricity generation	16.09 GT

TOP 20

Electricity Generation is only 5 of top 20

RANK	SOLUTION	SECTOR	REDUCED CO2
1	Refrigerant Management	Materials	89.74 GT
2	**Wind Turbines (Onshore)**	ELC Gen	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	59.60 GT
7	Family Planning	Women and Girls	59.60 GT
8	**Solar Farms**	ELC Gen	36.90 GT
9	Silvopasture	Food	31.19 GT
10	**Rooftop Solar**	ELC Gen	24.60 GT
11	Regenerative Agriculture	Food	23.15 GT
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15	Afforestation	Land Use	18.06 GT
16	Conservation Agriculture	Food	17.35 GT
17	Tree Intercropping	Food	17.20 GT
18	**Geothermal**	ELC Gen	16.60 GT
19	Managed Grazing	Food	16.34 GT
20	**Nuclear**	ELC Gen	16.09 GT

WIND TURBINES (ONSHORE)

#2
RANK BY 2050

86.6 GT
REDUCED CO2-eq

$1.23T
NET FIRST COST

$7.4T
NET OPERATIONAL SAVINGS

ROOFTOP SOLAR

#10
RANK BY 2050

24.6 GT
REDUCED CO2 -eq

$453B
NET FIRST COST

$3.46T
NET OPERATIONAL SAVINGS

WIND TURBINES (OFFSHORE)

#22
RANK BY 2050

14.1 GT
REDUCED CO2-eq

$542B
NET FIRST COST

$763B
NET OPERATIONAL SAVINGS

TOP 20

Food is
8 of top 20

RANK	SOLUTION	SECTOR	REDUCED CO2
1	Refrigerant Management	Materials	89.74 GT
2	Wind Turbines (Onshore)	Energy	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	59.60 GT
7	Family Planning	Women and Girls	59.60 GT
8	Solar Farms	Energy	36.90 GT
9	**Silvopasture**	Food	31.19 GT
10	Rooftop Solar	Energy	24.60 GT
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17	**Tree Intercropping**	Food	17.20 GT
18	Geothermal	Energy	16.60 GT
19	**Managed Grazing**	Food	16.34 GT
20	Nuclear	Energy	16.09 GT

REDUCED FOOD WASTE

#3
RANK BY 2050

70.53 GT
REDUCED CO2 -eq

PLANT-RICH DIET

#4

RANK BY 2050

66.11 GT

REDUCED CO2 -eq

COMPOSTING

#60
RANK BY 2050

2.28 GT
REDUCED CO2

$(63.7)B
NET COST

$(60.8)B
NET SAVINGS

MANAGED GRAZING

#19
RANK BY 2050

16.34 GT
REDUCED CO2-eq

$50.5B
NET FIRST COST

$735.3B
NET OPERATIONAL SAVINGS

TOP 20

Women and girls: when combined, it is top solution.

RANK	SOLUTION	SECTOR	REDUCED CO2
1	**Refrigerant Management**	Materials	89.74 GT
2	**Wind Turbines (Onshore)**	Energy	84.60 GT
3	**Reduced Food Waste**	Food	70.53 GT
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17	**Tree Intercropping**	Food	17.20 GT
18	**Geothermal**	Energy	16.60 GT
19	**Managed Grazing**	Food	16.34 GT
20	**Nuclear**	Energy	16.09 GT

EDUCATING GIRLS

#6

RANK BY 2050

59.60 GT

REDUCED CO2

FAMILY PLANNING

#7
RANK BY 2050

59.60 GT
REDUCED CO2 -eq

TOP 20

Materials is only one, but top solution

RANK	SOLUTION	SECTOR	REDUCED CO2
1	**Refrigeration**	Materials	89.74 GT
2	**Wind Turbines (Onshore)**	Energy	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
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18	**Geothermal**	Energy	16.60 GT
19	**Managed Grazing**	Food	16.34 GT
20	**Nuclear**	Energy	16.09 GT

REFRIGERANT MANAGEMENT

#1
RANK BY 2050

89.7 GT
REDUCED CO2-eq

$(903)B
NET OPERATIONAL SAVINGS

RECYCLED PAPER

#70
RANK BY 2050

0.9 GT
REDUCED CO2-eq

$573B
NET FIRST COST

Transport

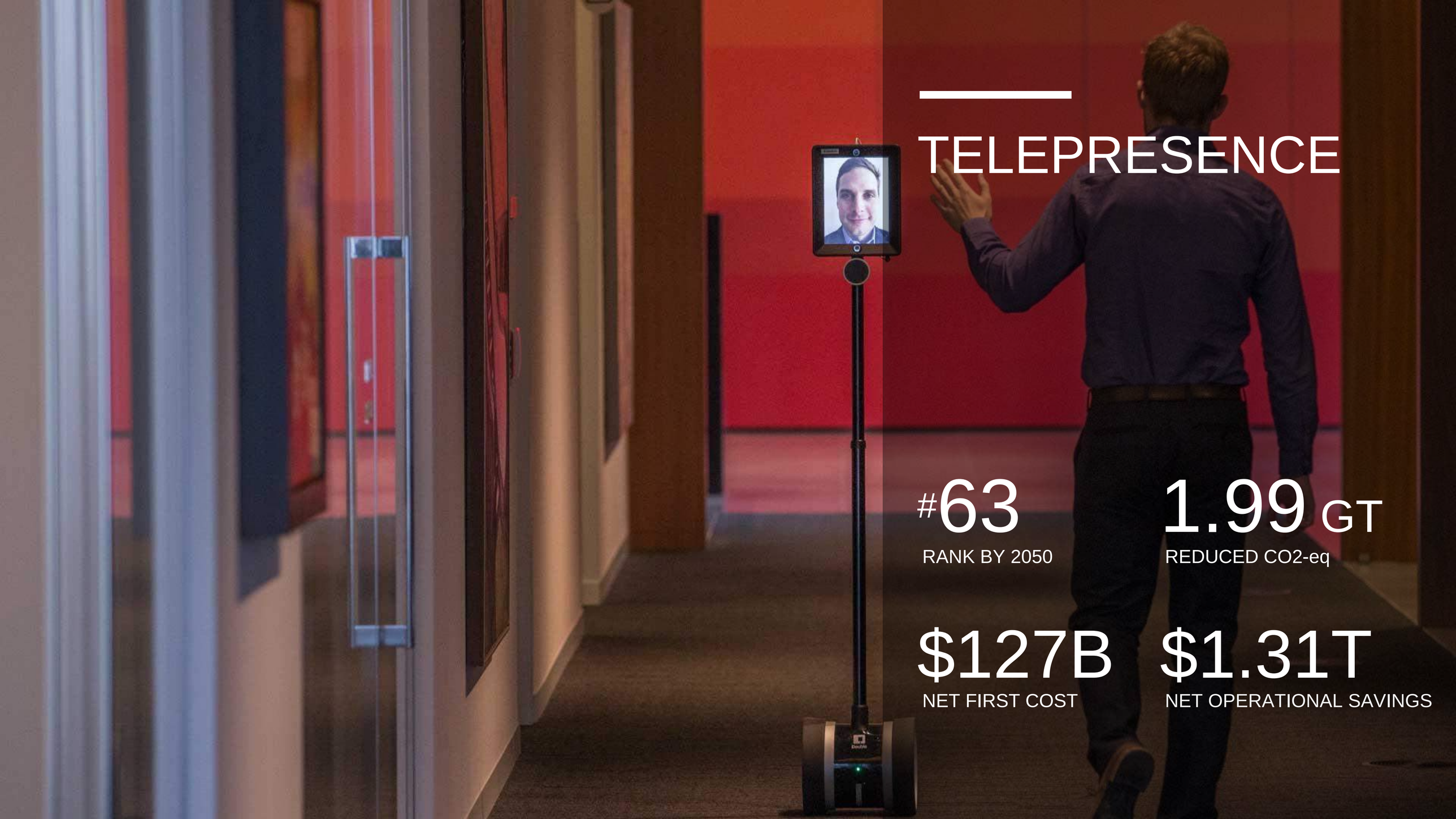
ELECTRIC VEHICLES

#26
RANK BY 2050

10.8 GT
REDUCED CO2 -eq

$14T
NET FIRST COST

$9.73T
NET OPERATIONAL SAVINGS



TELEPRESENCE

#63
RANK BY 2050

1.99 GT
REDUCED CO2-eq

$127B
NET FIRST COST

$1.31T
NET OPERATIONAL SAVINGS

Ecosystems and Forestry

FOREST PROTECTION

#38
RANK BY 2050

6.2 GT
REDUCED CO2 eq

896.2 GT
CO2 -eq PROTECTED

TROPICAL FORESTS

#5
RANK BY 2050

61.23 GT
REDUCED CO2-eq

Buildings and Cities

WATER DISTRIBUTION

#71
RANK BY 2050

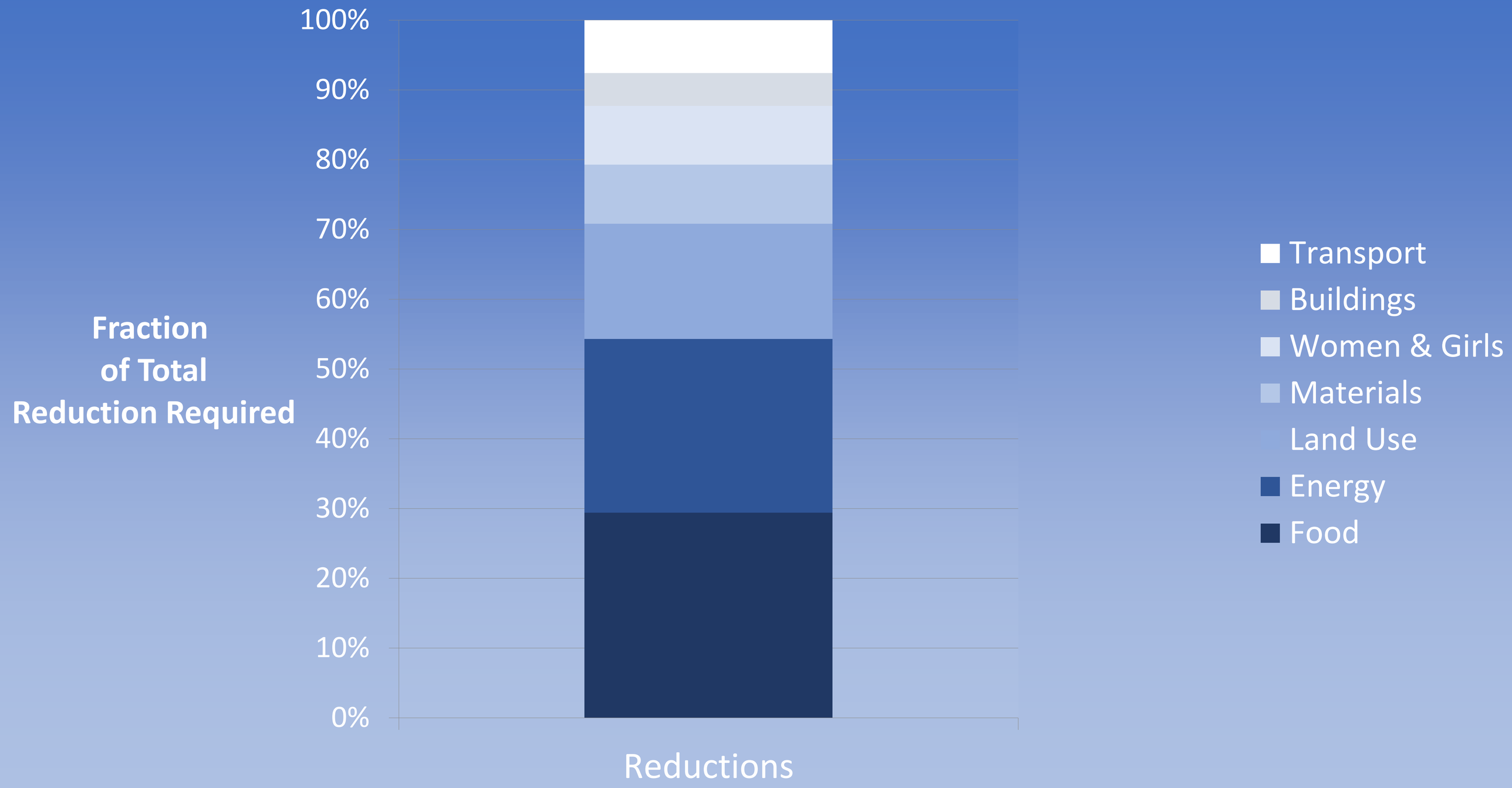
0.87 GT
REDUCED CO2

$137B
NET COST

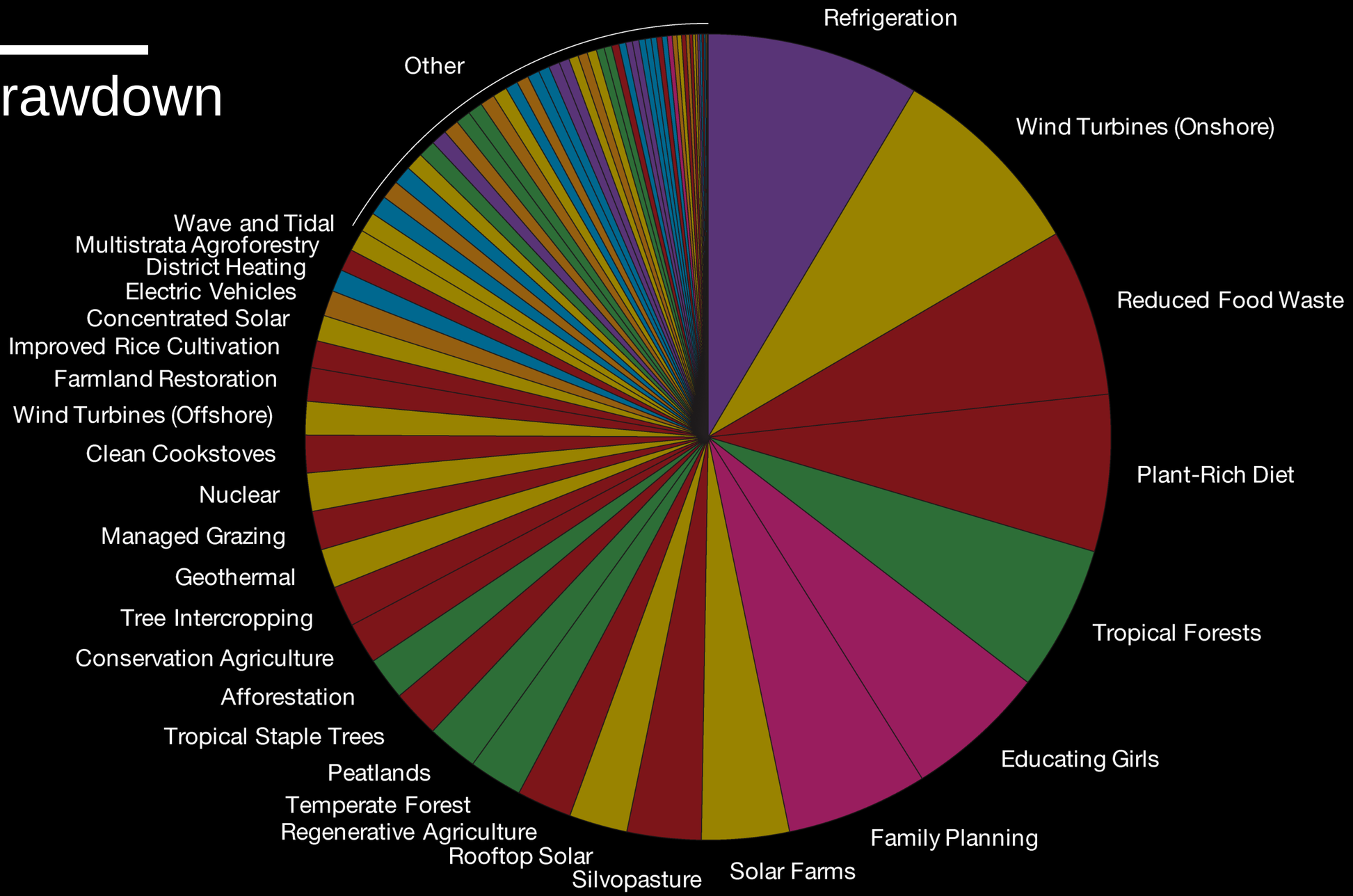
$903B
NET SAVINGS

Is Drawdown possible by 2050?

Target: Drawdown



Drawdown


Refrigeration
Wind Turbines (Onshore)
Reduced Food Waste
Plant-Rich Diet
Tropical Forests
Educating Girls
Family Planning
Solar Farms
Silvopasture
Rooftop Solar
Regenerative Agriculture
Temperate Forest
Peatlands
Tropical Staple Trees
Afforestation
Conservation Agriculture
Tree Intercropping
Geothermal
Managed Grazing
Nuclear
Clean Cookstoves
Wind Turbines (Offshore)
Farmland Restoration
Improved Rice Cultivation
Concentrated Solar
Electric Vehicles
District Heating
Multistrata Agroforestry
Wave and Tidal
Other

Coming Attractions


MARINE
PERMACULTURE

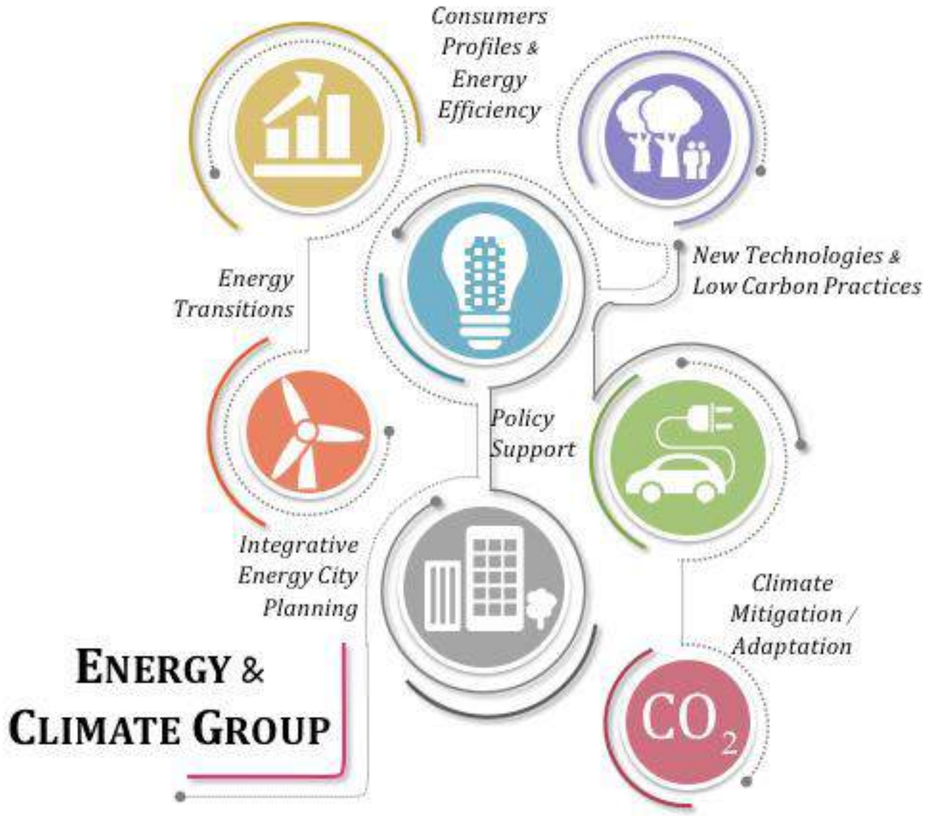
BUILDING WITH WOOD

ARTIFICIAL LEAF


A COW WALKS
ONTO A BEACH

CENSE
center for environmental
and sustainability research

FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA



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DRAWDOWN

https://www.cense.fct.unl.pt/

http://drawdown.org/