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WORLD ENERGY MARKETS OBSERVATORY

BALANCING THE FIGHT AGAINST CLIMATE CHANGE WITH ENERGY SECURITY

In collaboration with:

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CLIMATE CHANGE GLOBAL PERSPECTIVE (EMISSIONS, CONSUMPTION, RENEWABLES)

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The time is now or never, there is no alternative

Without immediate action, the world could become uninhabitable.

We are on a fast track to climate disaster: Major cities under water. Unprecedented heatwaves. Terrifying storms. Widespread water shortages. The extinction of a million species of plants and animals. It is what science tells us will result from our current energy policies.

We are on a pathway to global warming of more than double the 1.5-degree limit agreed in Paris. Some government and business leaders are saying one thing – but doing another. And the results will be catastrophic. This is a climate emergency.

This is not fiction or exaggeration. It is what science tells us will result from our current energy policies. We are on a pathway to global warming of more than double the 1.5° limit that was agreed in Paris in 2015. The science is clear. To keep the 1.5° limit, we need to cut global emissions by 45% this decade. But current climate pledges would mean a 14% increase in emissions.

Climate promises and plans must be turned into reality and action now. It is time to stop burning our planet and start investing in the abundant renewable energy all around us.[1]"

António Guterres
United Nations' Secretary-General, April 2022

1 António Guterres, United Nations' Secretary-General, 04 April 2022

The science is unequivocal and the action windows is rapidly closing, to delay action will trigger impacts of climate change so catastrophic and our world will become unrecognizable. Next few years offer a narrow window to realize a sustainable world for all. There is no alternative.

Compounding crises underscore the pressing need to accelerate the global energy transition. Events of recent years have accentuated the speed and the costs to the global economy of a centralized energy system highly dependent on fossil fuels. Oil and gas prices are soaring to new highs and the crisis in Ukraine brings new levels of concern and uncertainty. Additionally, the Covid-19 pandemic continues to hamper recovery effort and citizens worldwide worry about the affordability of their energy bills. The need for energy transition is urgent. The time is now or never.

At the same time, the impacts of human-caused climate change are increasingly evident around the globe[2]; between 3.3 and 3.6 billion people already live in settings highly vulnerable to climate change[3]. Therefore, short-term interventions to ameliorate challenges must be accompanied by a steadfast focus on a successful energy transition in the medium and long term.

Despite the urgency for change and after the Covid-19-induced dip in 2020, carbon emissions have risen every year since 2015, the year of the Paris Conference of the Parties (COP).

The carbon budget is finite, and it is running out. Further delays in reducing emissions could greatly increase the economic and social costs associated with trying to remain within the emissions budget[4].

The stimulus and recovery efforts associated with the pandemic have also proved a missed opportunity, with only 6% of the G20's $15 trillion in recovery funding in 2020 and 2021 being channeled towards clean energy.

Current path the global warming will exceed 2°C

Given the inadequate pace and scope of the transition, any action short of radical and immediate will diminish the chance of staying on the 1.5°C or even 2°C path.

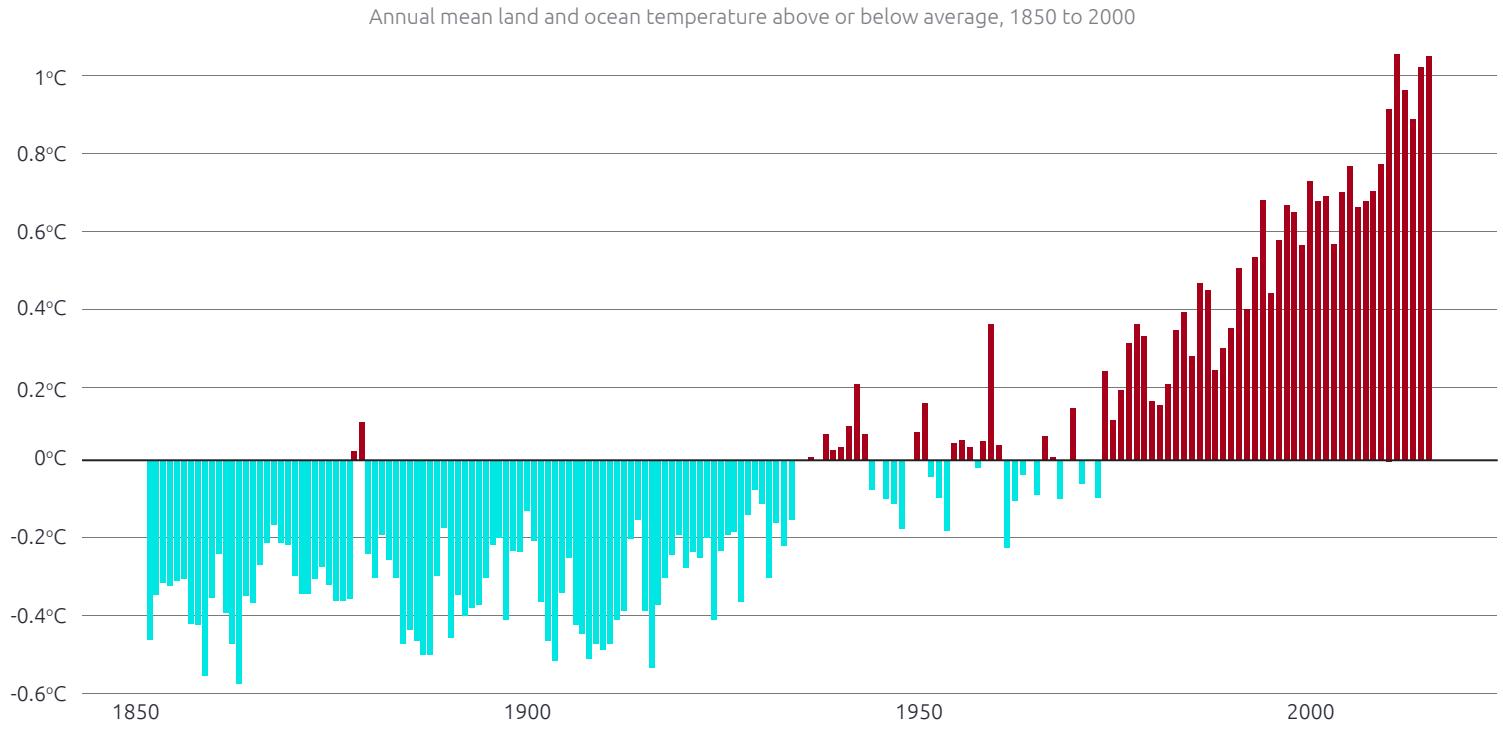
National climate pledges combined with other mitigation measures put the world on track for a 2.7°C temperature rise by the end of the century, above the threshold of 1.5°C. This could lead to catastrophic changes in the earth's climate. To keep global warming below 1.5°C this century, annual greenhouse gas (GHG) emissions will need to be halved in the next eight years[5]. The net zero emissions pledges could limit warming to 2.2°C, closer to the goal of the Paris Agreement. However, many national climate plans delay action until after 2030.

2 IRENA World Energy Transitions Outlook 2022 report
3 Intergovernmental Panel on Climate Change (IPCC)

4 BP Energy Outlook 2022 report
5 UNEP and UNEP CCC (Copenhagen Climate Centre) Emissions Gap report 2021

FIGURE 1

World is getting warmer



Note: Average calculated from 1951 to 1980 data

Source: University of California Berkeley

Every tenth of a degree of additional warming will escalate threats to people, species and ecosystems, even limiting global warming to 1.5ºC is not safe for all where for instance many glaciers around the world will either disappear completely or lose most of their mass; an additional 350 million people will experience water scarcity by 2030; and as much as 14% of terrestrial species will face high risks of extinction.

Nowadays between 3.3 billion-3.6 billion people live in countries highly vulnerable to climate impacts. For instance, in highly vulnerable nations, for example, mortality from droughts, storms and floods in 2010-2020 was 15 times greater than in countries with lower vulnerability[6].

Acceleration of the energy transition is also essential for long-term energy security, price stability, and national resilience. Some 80% of the global population lives in countries that are net energy importers. With the abundance of renewable potential yet to be harnessed, this percentage can be dramatically reduced[7].

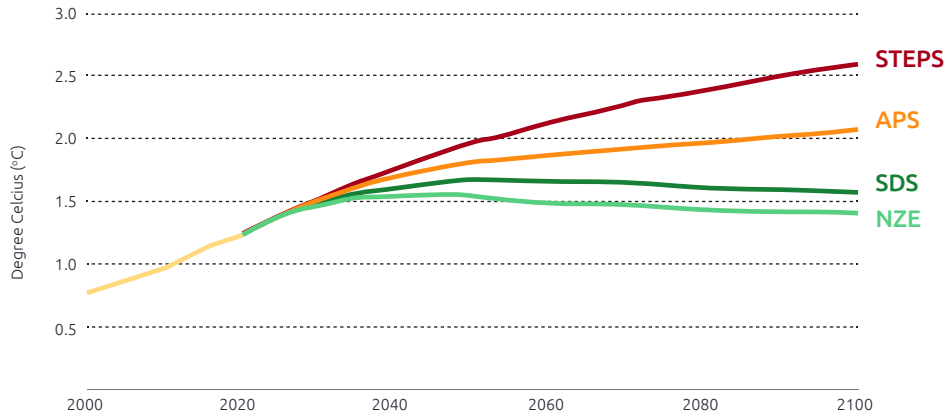
6 Intergovernmental Panel on Climate Change (IPCC) Climate Change 2022 – Impacts, Adoption and Vulnerability report
7 IRENA World Energy Transitions Outlook 2022 report

Global median surface temperatures rise over time under four scenarios, according to the World Energy Outlook 2021[8]:

- Net Zero Emissions by 2050 Scenario (NZE) is designed to achieve an emissions trajectory that limits the global temperature rise to 1.5°C without a temperature overshoot (with a 50% probability).
- Announced Pledges Scenario (APS) assumes that all climate commitments made by governments worldwide, including Nationally Determined Contributions (NDCs) and longer-term net zero targets, will be met in full and on time.
- Stated Policies Scenario (STEPS) reflects current policy settings based on a sector-by-sector assessment of the specific policies that are in place, as well as those that governments around the world have announced.
- Sustainable Development Scenario (SDS) pathway is consistent with the well below 2°C goal of the Paris Agreement.

FIGURE 2

Global median surface temperature rise over time



The temperature rise is 2.6°C in the STEPS and 2.1°C in the APS in 2100 and continues to increase.
It peaks at 1.7°C in the SDS and 1.5°C in the NZE around 2050 and then declines.

Source: IEA

8 IEA World Energy Outlook 2021 report

If the world stays on its current track temperatures, we are on average on a 2.7°C trajectory[9]. The difference between a warming of 2°C in spite of 1.5°C, only a difference of 0.5°C, the climate change consequences will be dramatic and catastrophic causing irreversible effects.

Many impacts of climate change have been observed worldwide, including: terrestrial effects; oceans and freshwater ecosystems; species shift and phenology; human systems (water scarcity and agriculture production); animal and livestock health and production; fisheries yield and aquaculture production; infectious diseases; malnutrition; displacement; floods; and storms causing damages[10].

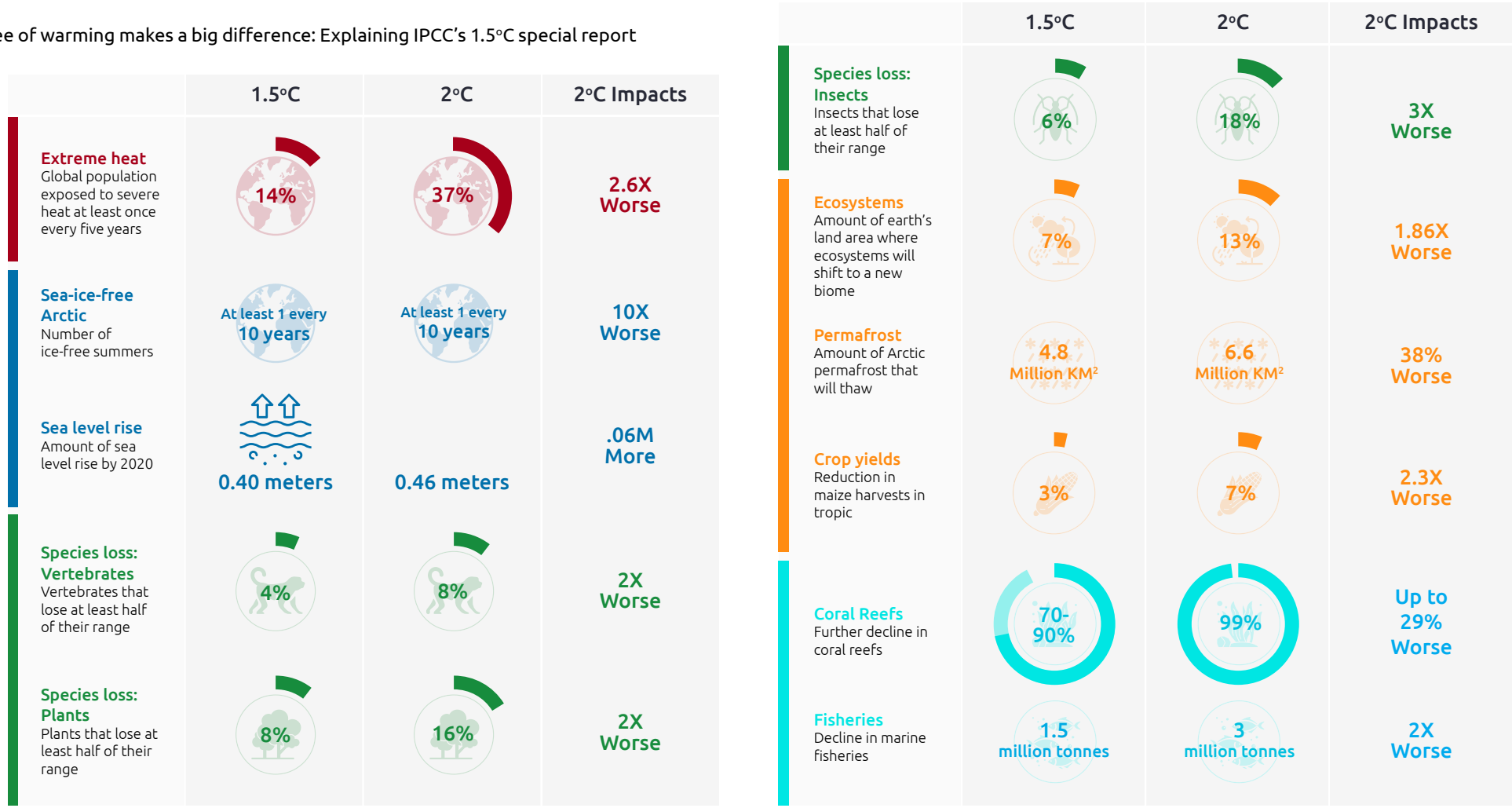
Even under the ambitious 1.5°C scenario, which will stave off much greater losses to nature and humans[11], the world will still face significant harm from climate change: coral reefs could decline as much as 90%; up to 14% of terrestrial species could face a very high risk of extinction; and 40% of megacities globally could record a heat index higher than 40.5°C (105°F).

Under the well below 2°C goal would put 10 million more people at risk from sea level rise and direct flood damage could be twice as high. At 3°C of warming, disruption to ports and coastal infrastructure could impact entire financial systems, and risks to agricultural yields are three times higher than at 2°C[12].

9 IPPC
10 Intergovernmental Panel on Climate Change (IPCC) Climate Change 2022 – Impacts, Adoption and Vulnerability report
11 Intergovernmental Panel on Climate Change (IPCC) Climate Change 2022 – Impacts, Adoption and Vulnerability report
12 Intergovernmental Panel on Climate Change (IPCC) Climate Change 2022 – Impacts, Adoption and Vulnerability report

FIGURE 3

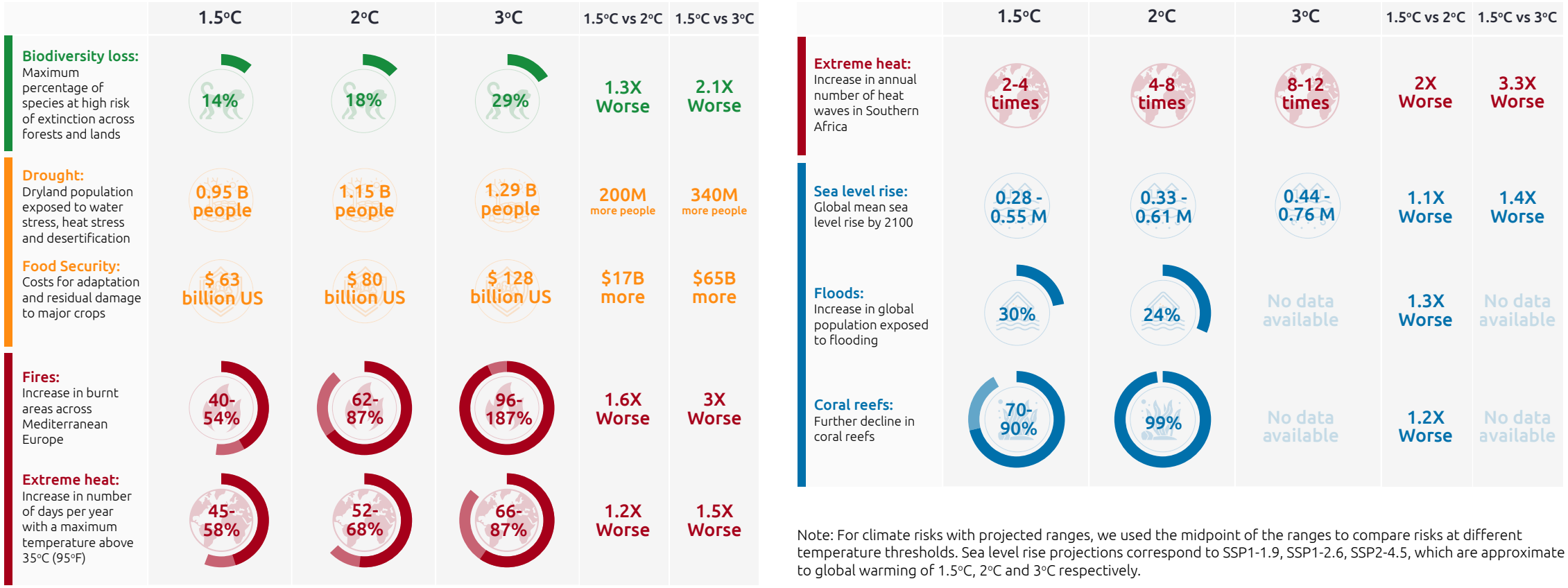
Half a degree of warming makes a big difference: Explaining IPCC's 1.5°C special report



Source: IPCC 2022 report

FIGURE 4

Comparing risks from rising temperatures: Explaining IPCC's working group II report (AR6)



Note: For climate risks with projected ranges, we used the midpoint of the ranges to compare risks at different temperature thresholds. Sea level rise projections correspond to SSP1-1.9, SSP1-2.6, SSP2-4.5, which are approximate to global warming of 1.5°C, 2°C and 3°C respectively.

Source: IPCC 2022 report

Insects, vital for pollinating crops and plants, are likely to lose half their habitat at 1.5°C. This becomes twice as likely at 2°C. The frequency and intensity of droughts, storms, and extreme weather events will rise with every increment in temperature – as we are already seeing with a global temperature increase over pre-industrial levels of around 1.1°C.

Extreme climate records were smashed in 2021 even worse than expected

From 1999 to 2018, there have been nearly 500,000 fatalities and close to $3.5 trillion of economic costs due to climate impacts worldwide, with China, India, Japan, Germany, and the U.S. being hit particularly hard in 2018.

Climate impacts are already more widespread and severe than expected causing widespread disruption in every region in the world with just 1.1ºC of warming as currently is today.

We are locked into even worse impacts from climate change in the near-term. For 2021, several climate change records were registered with extreme weather events[13]:

- A high temperature of 18.3°C was set in the Antarctic four times faster than the rest of the planet. Death Valley in California recorded the world's highest-ever temperature of 54.4°C. Italy set a new provisional European record in Syracuse (Sicily) with a temperature of 48.8°C. Kairouan (Tunisia) reached a record 50.3°C. Spain and Turkey also broke new national records, with temperatures of 47.4°C and 49.1°C, respectively.
- Sea levels rose 4.5 mm a year on average between 2013 and 2021. In the southwest Pacific, the southwest Indian Ocean and the south Atlantic, the sea level is rising substantially faster than the global average.

- The Antarctic ozone hole was larger and deeper than 70% of the ozone holes measured since 1979.
- Rain was recorded for the first time at Greenland's highest point, which is more than 3,200 meters above sea level. The area received several hours of rain and experienced air temperatures above freezing for about nine hours.
- Hurricane Ida wind speeds of 240 km per hour matched the strongest landfall on record for Louisiana in the United States, causing significant wind damage and flooding from storm surges with an estimated $75 billion in economic loss and 115 deaths. There were 21 named storms in 2021, well above the average of 14 per year between 1981 and 2010.
- The worst flooding ever was recorded in Western Europe. Hagen in western Germany reported 241 mm of rainfall in 22 hours. Germany reported 183 deaths and Belgium, 36.
- In July, the water levels in Lake Mead (a reservoir on the Colorado River in the southwestern U.S.) fell to 47 m below its full capacity, its lowest level on record. Drought also affected other parts of the world, including Canada, Iran, Pakistan, Afghanistan, Turkey, and Turkmenistan.

13 World Meteorological Organization (WMO), State of the Global Climate 2021 report

In the summer of 2022, Europe was hit by a climate-driven drought crisis with water shortages across the continent – possibly the worst in 500 years[14]:

In mid-August, the European Union (EU) registered a historical record of almost 660,000 hectares of land burned, especially affecting Spain, Romania, Portugal, and France, as well as in latitudes further north not usually affected, such as Slovenia, where the worst fires in generations were recorded[15].

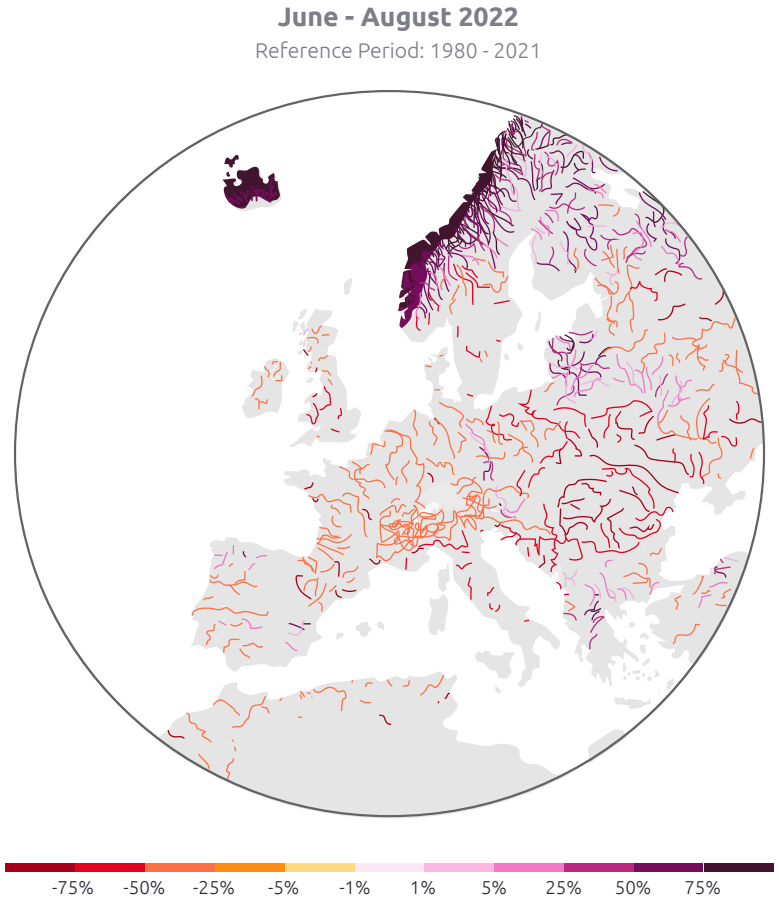
The English government officially declared a drought across southern and central England amid one of the hottest summers on record. The last eight months were the driest since 1976, which constrained water supply in the east of England; last July was the driest since 1935[16].

The Rhine, Germany's biggest waterway, could reach critically low levels around 35 centimeters. The Danube River authorities in Serbia have started dredging to keep vessels moving. The Po River, Italy's longest, is so low that barges and boats that sank decades ago are resurfacing. In Hungary, wide parts of Lake Velence near Budapest have turned into patches of dried mud.

A map of European rivers' discharge based on data from June to August 12, 2022, shows an average negative anomaly of -29% and reaching less than -62% at some points[17]:

FIGURE 5

River Discharge Anomaly



Source: Dr. Dominic Royé

Death Valley (California), America's driest place, recorded torrential rains with 75% of the average annual falling in just three hours in an extremely rare event – once per 1000 years. Future extreme storms and megafloods in California will occur with 200% to 400% greater probability than historical averages[18].

Drought crisis conditions were also reported in east Africa, the western United States, and northern Mexico.

After some of the highest recorded temperatures across South Asia, flooding in Pakistan, from the highest rainfall in more than three decades, killed more than 1,000 people and caused more than $10 billion in damage.

14 European Commission's Joint Research Center
15 EFFIS (European Forest Fire Information System)
16 UK Met Office weather agency
17 Data: GLOFAS Copemicus

18 https://www.science.org/doi/10.1126/sciadv.abq0995

A new global climate pact was reached at the COP26 summit

The 26th Conference of the Parties (COP26) of the United Nations took place in Glasgow from October 31 to November 12, 2021. The main topics discussed were nationally determined contributions and their accounting (article six of the Paris Agreement), adaptation plans, financing commitments, follow-up and analysis of the inadequacy of the resources and actions committed to date, and the need to increase climate action and ambition without pause, reinforcing the three main principles:

- Strengthen the credibility of advertisements – strengthen transparency mechanisms of compliance by all countries and the credibility of companies.
- Reinforce Solidarity – at the summit, this principle was made clearer than ever.
- Sense of urgency – in the middle of an emergency, the temperature increase should not exceed 1.5°C, and there is a large difference between 1.5°C and 2°C.

The main advances in the Glasgow Pact were[19]:

- To raise ambition at the national level, but more importantly, to spur immediate action and get started on reducing emissions. Establishment of a 2-year work program to define and achieve the Global Adaptation Goal of the Paris Agreement.
- To reaffirm the commitment to mobilize $100 billion-a-year. Define the goal for 2025 to finance the climate transition of developing countries and stimulate the large-scale private finance needed to reach the Paris Agreement.
- To encourage solutions that can reduce GHG emissions while also adapting to climate impacts like extreme weather events. Proposal for measures to reduce the gap between commitments and scientific evidence. The need to reduce emissions by 45% by 2030, compared to 2010, is specified to achieve compliance with the objective of not increasing the temperature by more than 1.5°C.
- Importance of the need to deal with the catastrophic impacts of climate change in vulnerable countries.
- Approval of the Paris Agreement rulebook, the market and cooperation mechanisms, the transparency framework, and the common deadlines for country contributions.
- Carbon dioxide emissions: To pledge further cuts to CO_2 emissions in 2022, keeping the goal of temperature rises within 1.5°C. Current pledges, if met, will only limit global warming to about 2.4°C.
- Methane emissions: Cut 30% of methane emissions by 2030, currently responsible for a third of human-generated warming. The biggest methane emitters China, Russia and India didn't joined.
- Coal: For the first time at COP, there was an explicit plan to reduce the use of coal, which is responsible for 40% of annual CO_2 emissions, but in a weaker commitment to "phase down" rather than "phase out."
- Fossil fuel subsidies: To phase-out subsidies that artificially lower the price of coal, oil, or natural gas.
- Forests: more than 100 countries with about 85% of the world's forests agreed to stop deforestation by 2030, which is vital to absorbing vast amounts of CO_2.

19 www.unep.org

Carbon emissions have rebounded quickly after the Covid-19 dip

In 2020, the Covid-19 pandemic lockdowns led to a 5.4% global drop in CO_2. In 2021, levels were similar to the record high of 2019. Emissions increased by 4.9%[20], pushing the CO_2 levels to the highest in the last two million years, closing the carbon budget threshold to limit the temperature increase to the critical figure of 1.5°C.

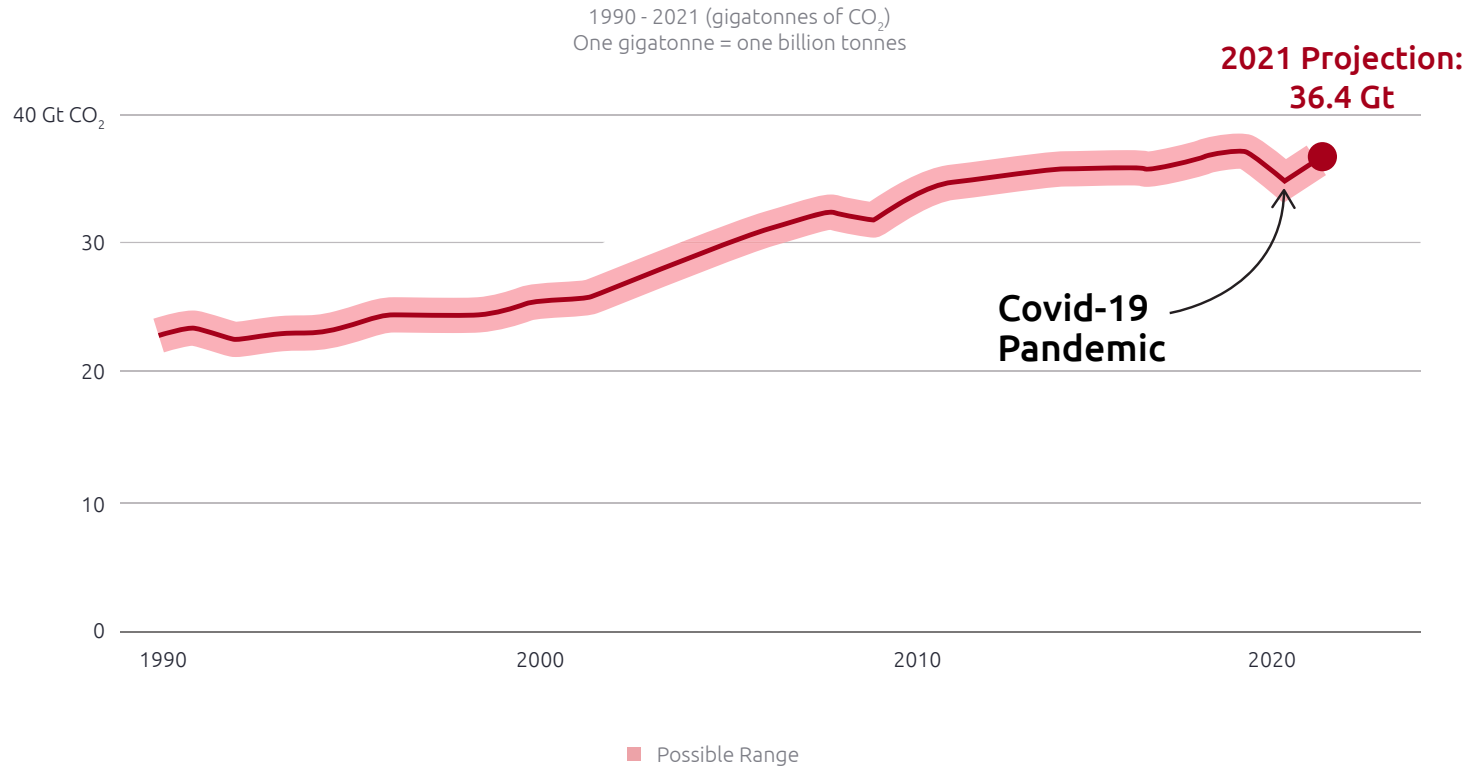
Important pledges were struck at the COP26 on limiting emissions of CO_2 and methane and on curbing deforestation, but the rapid rebound in emissions is at odds with the ambitious CO_2 cuts required to limit global temperature rise to 1.5°C. If we continue along as we are and don't cut emissions, there's a 50% likelihood of reaching the 1.5°C of warming in about 11 years[21] by the early 2030s[22].

To limit climate change to 1.5°C, we will need to cut global emissions by 1.4 billion tonnes of CO_2 yearly. The level in the fall of 2020 was 1.9 billion tonnes during the lockdown[23]. So, reducing emissions by roughly the equivalent in the post-lockdown period presents a huge challenge.

Only 17-19% of pandemic economic recovery ($438 billion out of $2.28 trillion) is being used for green recovery and reducing GHG emissions. Of the green recovery, 90% comes from seven countries, which needs to be expanded[24].

FIGURE 6

Global Carbon Emissions returning to pre-Covid levels



Source: Global Carbon Budget 2021

20 Climate Action Tracker, Global Carbon Project.
21 16th annual Global Carbon Budget report
22 IPCC
23 16th annual Global Carbon Budget report
24 UNEP (United Nations Environment Programme) Emisions gas report 2021.

The 1.5°C scenario by 2030 will require investments of $5.7 trillion per year until 2030. Investment decisions are long-lived, and the risks of stranded assets are high, so decisions

should be guided by long-term ratioale. $0.7 trillion in annual investments in fossil fuels should be redirected towards energy transition technologies, which could create close to 85 million additional energy transition-related jobs and boost global GDP (gross domestic product).[25]

There is a huge gap between where GHG emissions are predicted to be in 2030 based on current government commitments and where we need to be to meet the targets of the Paris Agreement. Current commitments put the world on track for a global temperature rise of 2.7°C by the end of the century.

Current commitments will only take 7.5% off predicted 2030 emissions, while a 55% reduction is needed to meet the 1.5°C targets. Any temperature increase approaching 2.7°C will be a disaster for humanity and many of the planet's species. Even an increase of 2°C would have a major impact on food, security, and human health[26].

To stand a chance of limiting global warming to 1.5°C, the next eight years will be crucial. GHGs need to be halved. On top of the current commitments, a further 28 gigatonnes of CO_2 equivalent ($GtCO_2e$) of annual emissions must be reduced.

Methane is crucial for short-term climate action. This gas has a global warming potential of more than 80 times that of carbon dioxide over 20 years, making it a powerful heat trapper. However, it only stays in the atmosphere for 12 years, far less than carbon dioxide, so reducing methane emissions can have a faster impact on reducing global warming in the short term.

Carbon markets will also help slash emissions with clearly defined rules and target actual reductions while being supported by arrangements to track progress and transparency[27].

25 IRENA World Energy Transitions Outlook 2022 report
26 Intergovernmental Panel on Climate Change (IPCC)

27 UNEP and UNEP CCC (Copenhagen Climate Centre) Emissions Gap report 2021

GHG emissions caused by humans are still increasing and will peak in 2025

Greenhouse gas emissions caused by humans are still increasing. The emissions reductions from actions have been lower than the emissions increase that comes from rising global activity. However, the growth rate of emissions was slower between 2010 and 2019 than between 2000 and 2009. To limit global warming to 1.5°C, GHG emissions would have to peak before 2025, be reduced by 43% by 2030 in the pathway to achieve net zero carbon dioxide emissions globally in 2050[1]. A 43% decrease in five years seems too much challenging or almost impossible to meet.

The 1.5°C pathway requires a massive change in how societies produce and consume energy and would result in a cut of nearly 37 gigatonnes of annual CO_2 emissions by 2050[2].

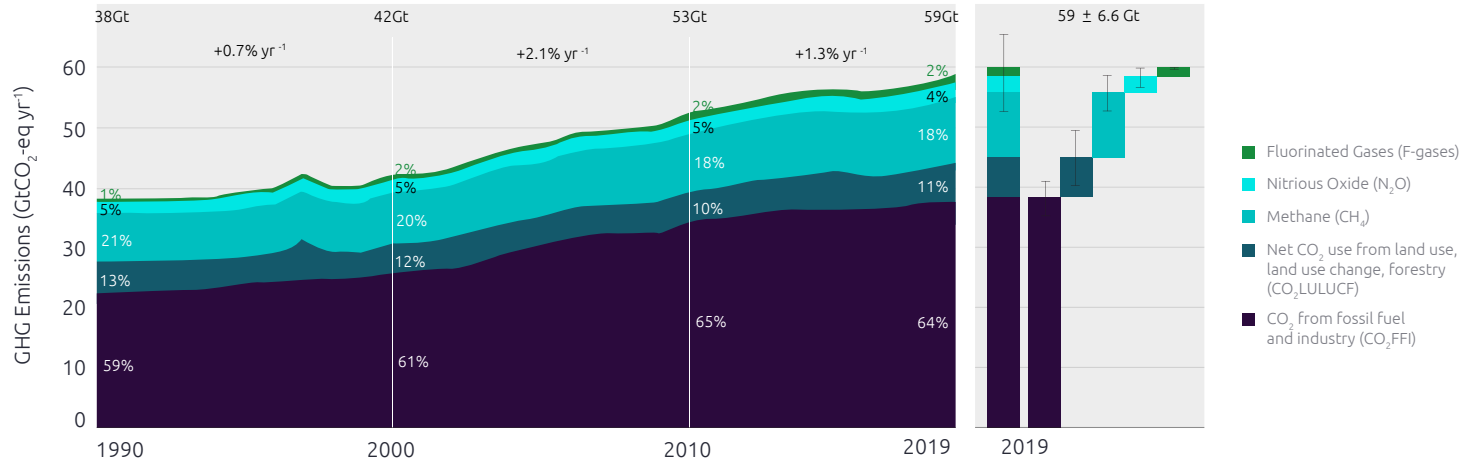
Fossil fuels accounted for 82% of primary energy use in 2021, up from 83% in 2019 and 85% five years ago; CO_2 emissions from energy use, industrial processes, flaring, and methane emissions increased 5.7% in 2021 to 39.0 $GtCO_2e$, and carbon dioxide emissions from energy increased 5.9% to 33.9 $GtCO_2$, close to 2019 levels[3].

GHG emissions have overwhelmingly come from more developed countries and wealthier individuals[4] being climate change the result of more than a century of unsustainable energy and land use, lifestyles, and patterns of consumption and production.

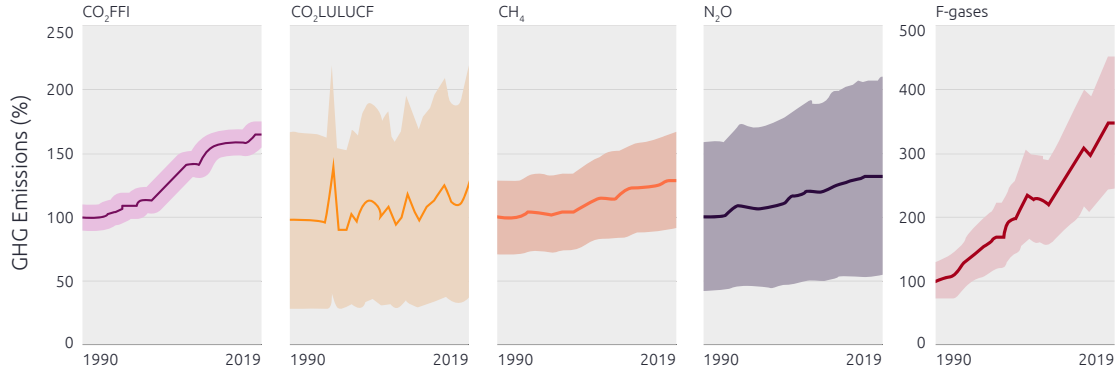
FIGURE 7 & 8

Global net anthropogenic GHG emissions have continued to rise across all major groups of greenhouse gases

7. Global net anthropogenic GHG emissions, 1990-2019



8. Global anthropogenic GHG emissions and uncertainties by gas – relative to 1990



The solid line indicates central estimate of emissions trends. The shaded area indicates the uncertainity range.

	2019 Emissions ($GtCo_2$-eq)	1990 - 2019 Emissions (Gt-Co_2-eq)	Emissions in 2019, relative to 1990 (%)
CO_2FFI	38 ± 3	15	167
$CO_2LULUCF$	6.6 ± 4.6	1.6	133
CH_4	11 ± 3.2	2.4	129
N_2O	2.7 ± 1.6	0.65	133
F-gases	1.4 ± 0.41	0.97	354
Total	59 ± 6.6	21	154

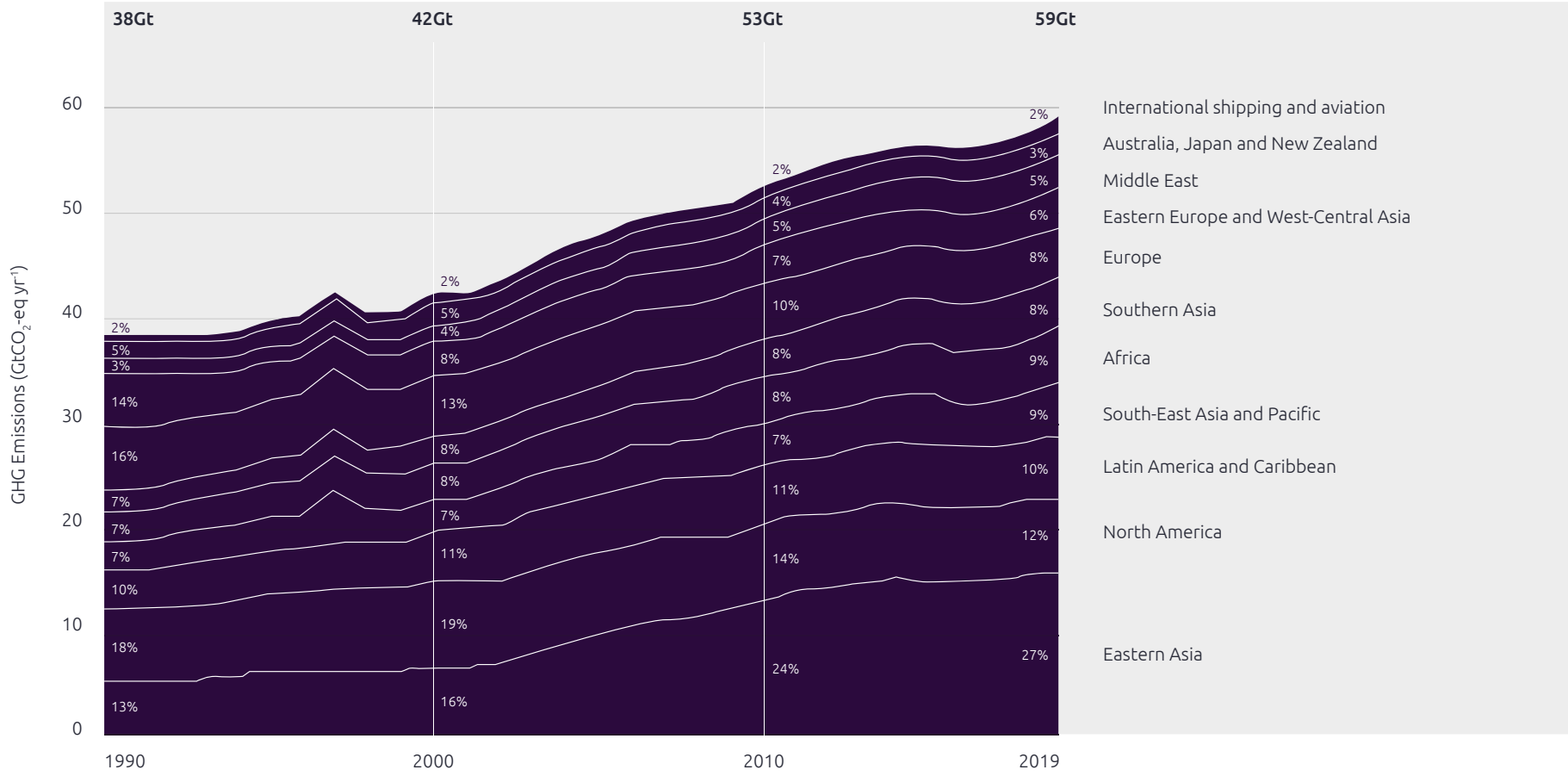
Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

1 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report.
2 IRENA World Energy Transitions Outlook 2022 report
3 BP Energy Outlook 2022 report
4 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report.

FIGURE 9a

Emissions have grown in most regions but are distributed unevenly, both in present day and cumulatively since 1850.

Global net anthropogenic GHG emissions by region, 1990-2019



Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

FIGURE 9b

Historical cumulative net anthropogenic CO2 emissions per region, 1850-2019

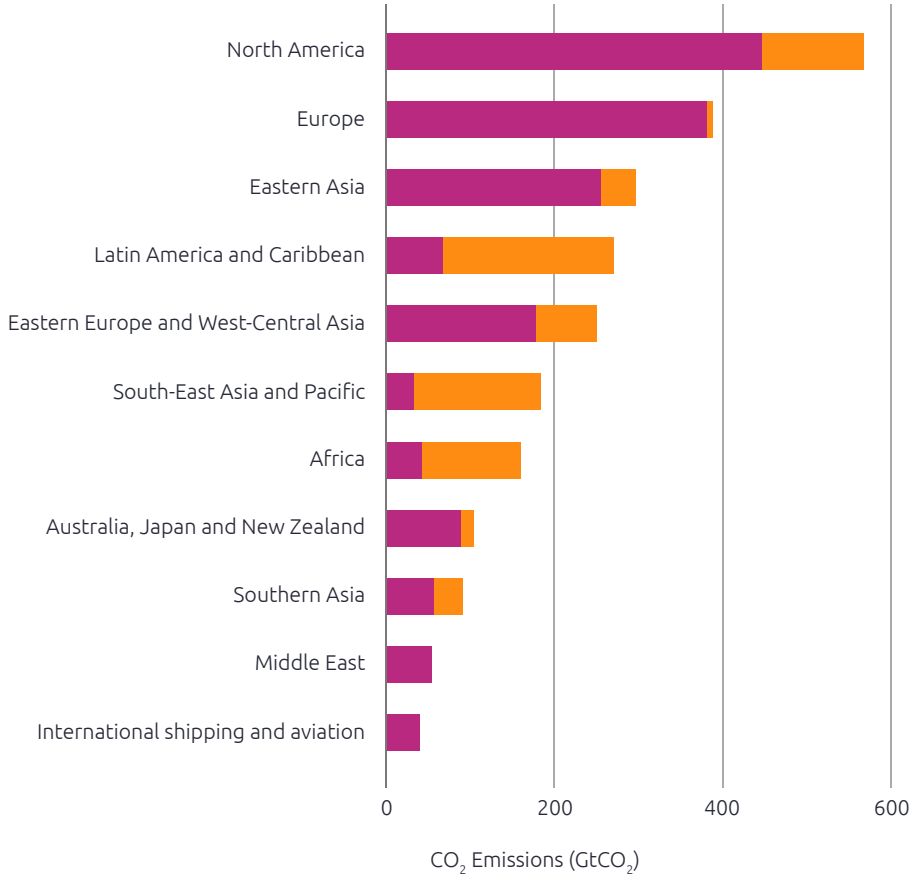
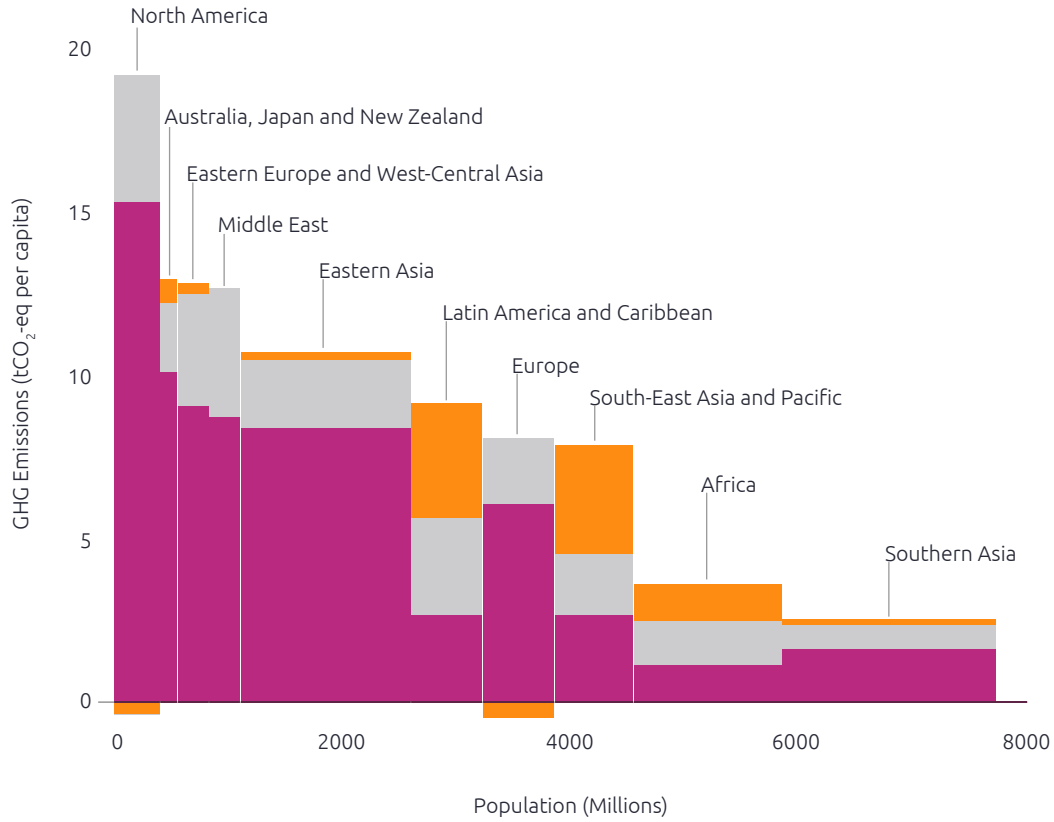


FIGURE 9c

Net anthropogenic GHG emissions per capita and for total population, per region (2019)



Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

FIGURE 9d

Regional indicators (2019) and Regional production vs consumption accounting (2018)

	Africa	Australia, Japan, New Zealand	Eastern Asia	Eastern Europe, West-Central Asia	Europe	Latin America and Caribbean	Middle East	North America	South-East Asia and Pacific	Southern Asia
Population (million persons, 2019)	1292	157	1471	291	620	646	252	366	674	1836
GDP per capita (USD1000$_{ppp}$2017 per person)[1]	5.0	43	17	20	43	15	20	61	12	6.2
Net GHG 2019[2] (production basis)										
% GHG contributions	9%	3%	27%	6%	8%	10%	5%	12%	9%	8%
GHG emissions intensity (tCO_2-eq / USD1000$_{ppp}$2017)	0.78	0.30	0.62	0.64	0.18	0.61	0.64	0.31	0.65	0.42
GHG per capita (tCO_2-eq per person)	3.9	13	11	13	7.8	9.2	13	19	7.9	2.6
CO_2FFI, 2018, per person										
Production-based emissions (tCO_2FFI per person, based on 2018 data	1.2	10	8.4	9.2	6.5	2.8	8.7	16	2.6	1.6
Consumption-based emissions (tCO_2FFI per person, based on 2018 data	0.84	11	6.7	6.2	7.8	2.8	7.6	17	2.5	1.5

[1] GDP per capita in 2019 in USD2017 currency purchasing power basis
[2] GIncludes CO_2FFI, CO_2LULUCF and Other GHGs, excluding international aviation and shipping

Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

Renewables, energy efficiency, and electrification will dominate the energy transition

Renewables technologies, energy efficiency, and electrification will dominate energy transition. In 2050, 90% of all decarbonization will involve renewable energy through a direct supply of low-cost power, efficiency, electrification, bioenergy with carbon capture and storage (CCS), and green hydrogen[5].

A radical shift in energy demand should be accelerated to reach the Paris Agreement's declining role for fossil fuel sources and an accelerated and rapid expansion in renewables and electrification to substitute fossil fuels, in this context the use of low carbon technologies like nuclear will play a crucial role also.

5 IRENA World Energy Transitions Outlook 2022 report

Renewables must accelerate and triple their installation pace

Renewables-based electricity is now the cheapest power option in most regions. The global weighted-average levelized cost of electricity from newly commissioned utility-scale solar photovoltaic (PV) projects fell by 85% between 2010 and 2020. The corresponding cost reductions for concentrated solar power (CSP) were 68%, onshore wind was 56%, and offshore wind was 48%[6], but the speed of the shift to renewable energy must triple[7].

Renewables accounted for more than two-thirds of investment in new power capacity in 2021[8], yet a sizeable gain in coal and oil use have caused the second largest annual increase in climate change-causing CO_2 emissions[9].

Nowadays the situation has become specially complex due to current geopolitical energy crisis, high electricity, oil and gas prices, extremely high level of inflation, cost of capital increasing, constraints and price increasing in raw materials supply, accelerated increase in the demand side, high dependency on Chinese critical minerals, manufacturing and logistics, and finally more ambitious and accelerated renewables goals. This is causing a crossroads and a perfect storm situation in the renewables industry. Yet, definitely renewables remain the major option today to decarbonize the largest part of the economy.

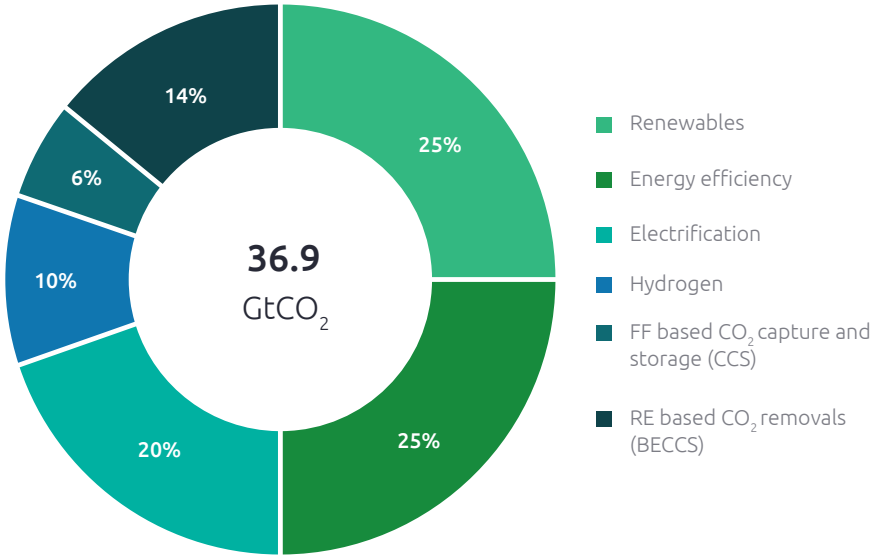
6 IRENA World Energy Transitions Outlook 2022 report
7 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report, IEA
8 IEA (International Energy Agency)
9 IEA (International Energy Agency)

Green electricity is a quick and cheap option to clean the electricity sector and electrify the whole economy as much as possible, being a radical acceleration needed to change the current trajectory. The energy transition is far from being on track to 1.5°C. Achieving the net zero target in 2050 will depend on sufficient action for this decade[10].

10 IRENA World Energy Transitions Outlook 2022 report

FIGURE 10

Reducing emissions by 2050 through six technological avenues



Source: IRENA World Energy Transitions Outlook 2022

FIGURE 11

Tracking progress of key energy system components

	Indicators	Recent Years	2050	Off/On track
RENEWABLES	Share of renewables in electricity generation	26%	90%	
	Modern bioenergy consumption	18 EJ	58 EJ	
ENERGY EFFICIENCY	Investment needs for energy efficiency	0.3 USD trillion/yr	1.5 USD trillion/yr	
ELECTRIFICATION	Passenger electric cars on the road	7 million/yr	147 million/yr	
HYDROGEN	Clean hydrogen production	0.8 Mt	614 Mt	
CCS AND BECCS	CCS and BECCS to abate emissions in industry	0.04 GtCO2 captured/yr	8.4 GtCO2 captured/yr	

Source: IRENA World Energy Transitions Outlook 2022

Energy transition will be underpinned by a range of low-carbon energy sources (nuclear, biofuels and biogases) also and technologies for transition pathways, especially for transport (aviation, maritime, heavy road) and industrial thermal processes, until green hydrogen can be deployed massively and widely used for the next decades.

FIGURE 12

Unit costs of some forms of Renewable energy and batteries for passenger EVs have fallen, and their use continues to rise

Source: UBS Asset Management, MSCI. Index Holdings as of 28 February 2022, ESG data as of 02 March 2022

China, the U.S., the European Union, India, and Russia are responsible for most of the world's CO_2 emissions

The G20 group is responsible for around 75% of global emissions[11], being China, the U.S., the European Union, India, and Russia responsible for most of the world's emissions of CO2 and GHG responsible for global warming.

China is the world's biggest emitter, responsible for nearly 30% of the global carbon emissions[12]; its emissions are still rising largely because of a reliance on coal. China's emissions increased 5.5% in 2021 and carbon emissions will peak before 2030. The country is aiming for 25% of energy from non-fossil fuels by 2030 and expecting to be carbon neutral before 2060, considering measures to absorb it from the atmosphere.

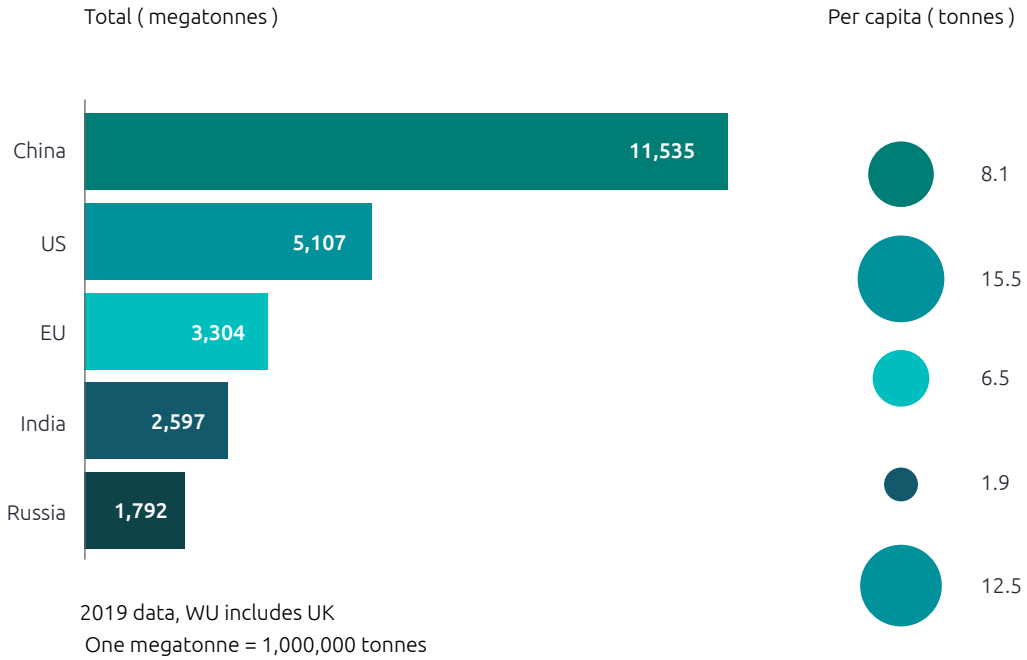
CO2 increased by 4% across the G20 group in 2021, after dropping 6% in 2020 due to the pandemic[13]. China and India exceeded their 2019 emissions levels, China being responsible for around 60% of the rise[14], mostly due to coal use.

Coal consumption rose by almost 5% for 2021, reaching its record that year. China accounted for 61% of the growth, the U.S. for 18%, and India for 17%[15].

11 Climate Transparency report
12 Global atmospheric research
13 Climate Transparency report
14 Climate Transparency report
15 Climate Transparency report

FIGURE 13

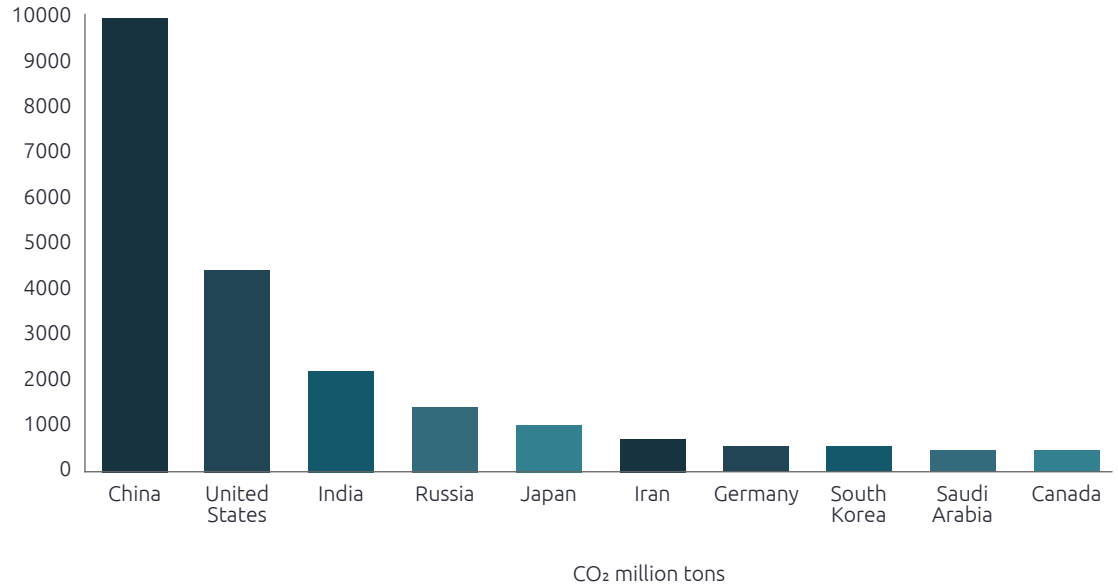
Countries which emit the most CO_2



Source: EC, Emissions database for Global atmospheric research

FIGURE 14

Top 10 ranking of the most CO_2 polluting countries in the world in 2020



Source: BP Statistical Review of World Energy 2021

FIGURE 15

CO_2 emissions per person in 2017 (in tons per capita):

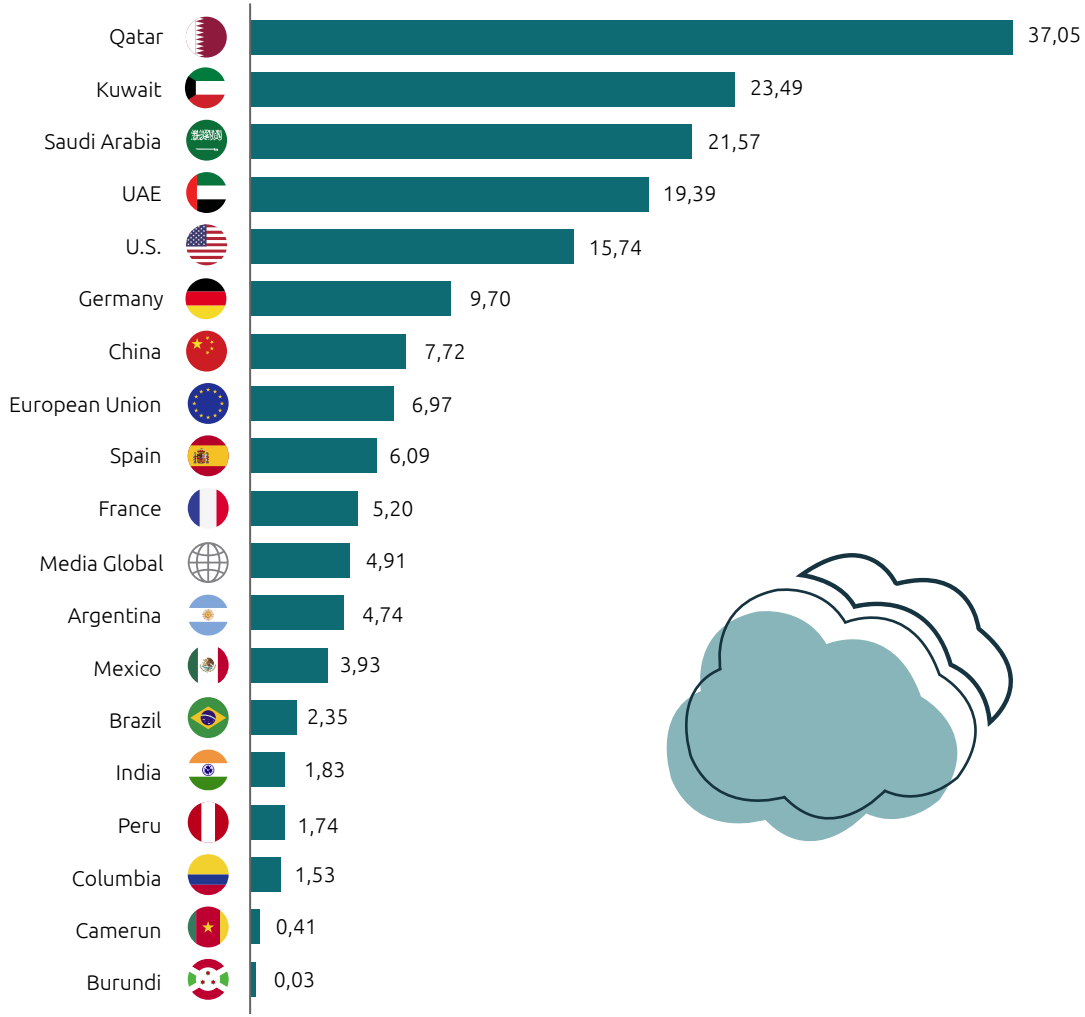
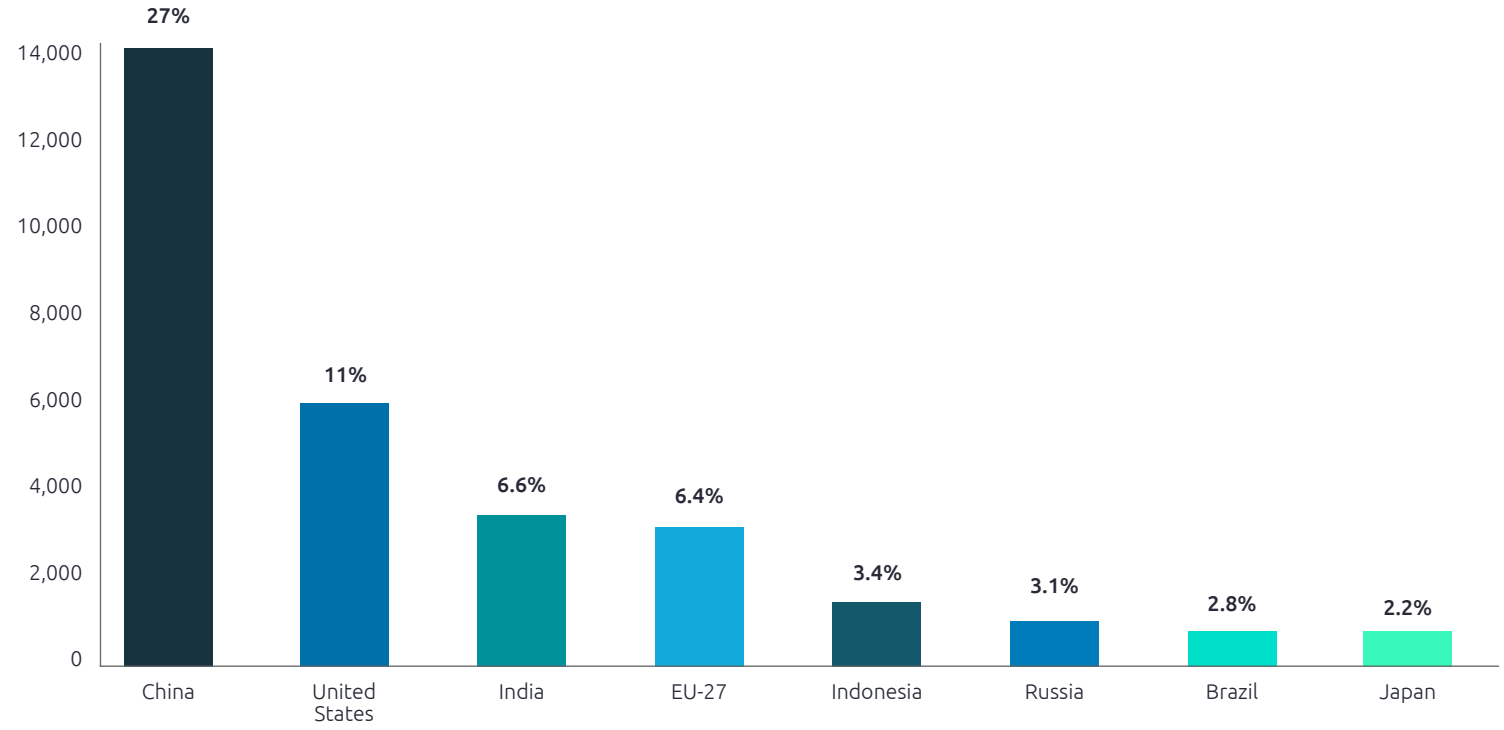


FIGURE 16

Ranking of the most GHG emissions producing countries

GHG emission %



Source: Rhodium Group

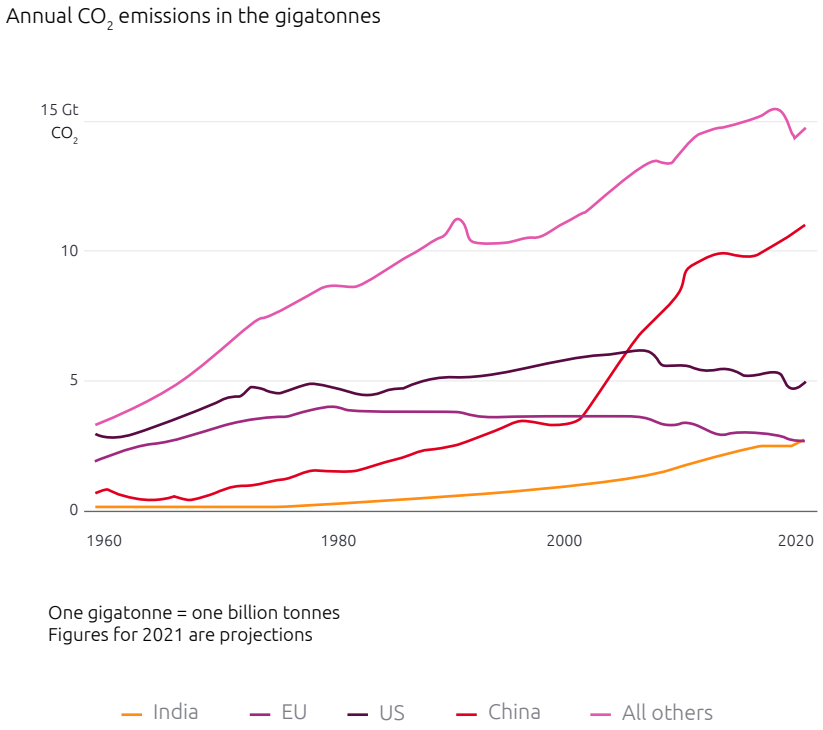
China is the largest producer of CO_2 and its carbon emissions. Recently, China announced it would stop funding new coal-fired projects overseas, but at home coal mines have been ordered to ramp up production to meet surging energy demand. China expects to cut back on coal use from 2026. China has not joined the pledge made at the climate summit by more than 100 countries to reduce emissions of other GHG, mainly methane, by 30% by 2030.

On the other side China accounts for more than one-third of all global solar power and is the world's biggest producer of wind energy by far; it has switched to low-carbon energy sources faster than many other countries. At the same time, China is deploying electric buses and electric vehicles, but industrial sectors such as construction, steel, and cement still require a high intensity of coal. China needs to cut demand for coal by more than 80% by 2060 to meet its climate goals[16].

16 International Energy Agency

FIGURE 17

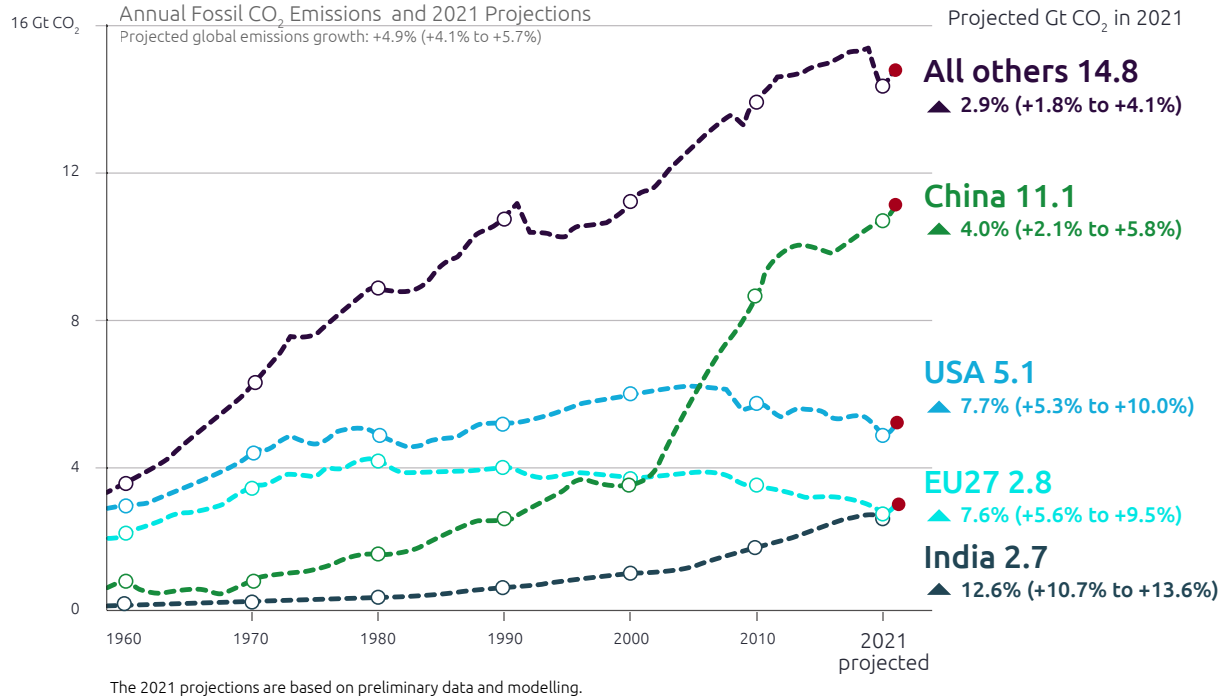
China's emissions are still rising



Source: Global Carbon Budget 2021

FIGURE 18

Global fossil CO_2 emissions are projected to increase by 4.9% (4.1%-5.7%) in 2021

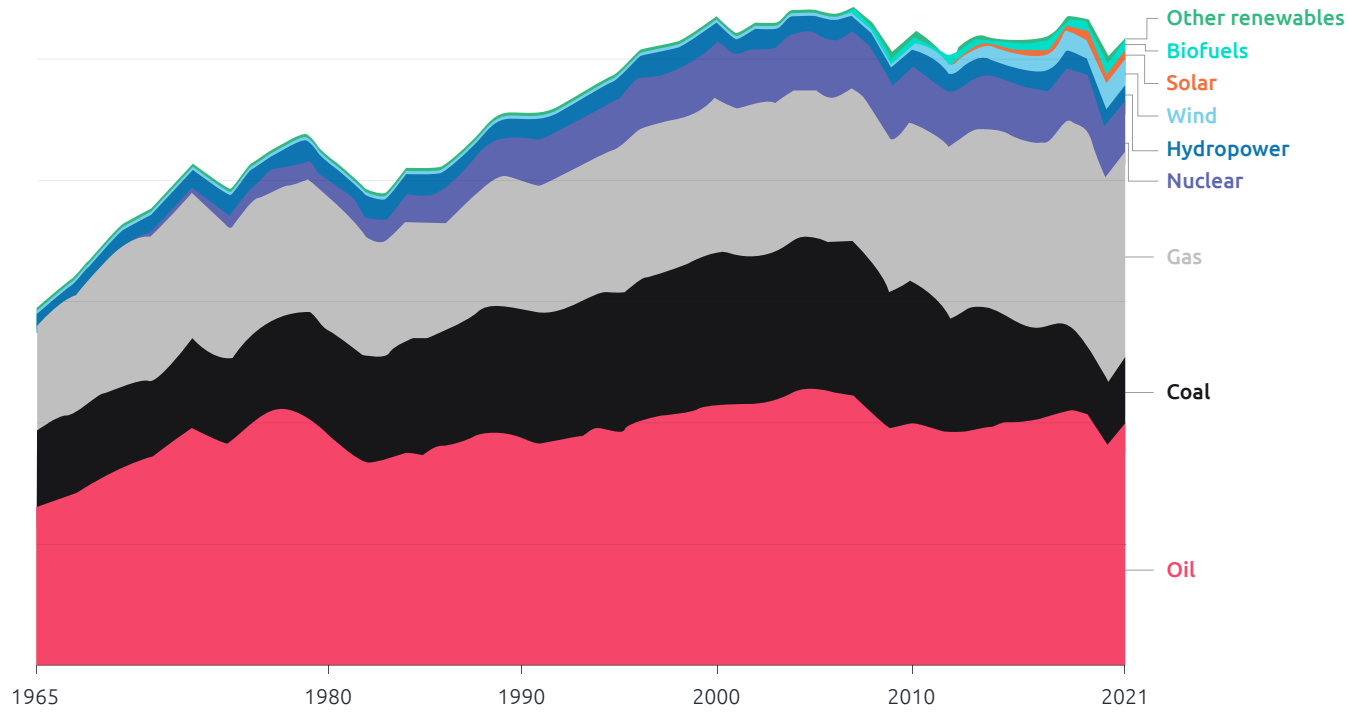


Source: Global Carbon Project: Global Carbon Budget 2021 report

FIGURE 19

Energy consumption by source, United States

Primary energy consumption is measured in terawatt-hours (TWh). Here an inefficiency factor (the substitution method) has been applied for fossil fuels, meaning the shares by each energy source give a better approximation of final energy consumption



Note: "Other renewables" includes geothermal, biomass and waste energy.

Source: https://ourworldindata.org/energy-mix https://

Emissions in India were 4.4% higher in 2021 than in the 2019 pre-pandemic level. Nevertheless, and fortunately, 2021 emissions in the U.S., European Union, and the rest of the world remained 3.7%, 4.2%, and 4.2%, respectively, below their 2019 levels due to policies designed to reduce emissions from fossil fuels.

The U.S. has the most emissions per person at 4.9 tCO_2/capita (followed by Australia at 4.1 tCO_2/capita with the G20 average of 1.4 tCO_2/capita)[1] and will cut CO_2 by at least 50% of the 2005 level by 2030. The US currently is getting more than 80% of energy supply from fossil fuels although renewable energy sources is increasing significantly yearly. The U.S. expects half of new vehicles to be electric by 2030 and carbon-neutral by 2050 because of a clean-electricity program to reward utility companies for switching from fossil fuels. CO_2 emissions have been dropping over the past decade, but it's not sufficient and substantial improvement is needed to reach the Paris Agreement[2].

1 Climate Transparency report
2 Climate Action Tracker

In a joint statement at the COP26 summit, the U.S. and China pledged 100% carbon pollution-free electricity by 2035. However, the pledge was subsequently broken in response to Taiwan support.

The European Union expects a 55% emissions cut from the 1990 level by 2030, 40% of energy from renewables by 2030, and to be carbon neutral by 2050. The top CO2 emitters are Germany, Italy, and Poland due to the high dependency on fossil fuels, especially coal. It is currently even more complex a situation due to the Ukraine war and dependency on Russian gas.

The European Union negotiates as a single entity at COP26, but all members need to agree on how to reach the targets as a whole. Its policies and actions are almost sufficient to keep the global temperature rise to less than 2°C[17].

India is highly reliant on coal and is aiming for a 45% reduction in emissions intensity by 2030, expecting 50% of electricity capacity from non-fossil fuels by 2030, and reaching net zero by 2070. CO2 annual emissions have risen steadily in the past decades, but India produces the lowest emissions per person among the largest emitters, with a target for cutting CO2 emissions intensity per unit of economic growth.

India is significantly increasing its clean energy production from wind, solar and hydropower, reaching 23% by 2019. However, about 70% of the electricity grid is powered by coal, and being a major methane emitter, it has not joined the methane emissions reduction initiative at COP26. India needs to phase out coal power generation before 2040 and boost its target for clean energy sources[18].

17 Climate Action Tracker
18 Climate Action Tracker

FIGURE 20

Per capita energy from fossil fuels, nuclear and renewables, 2021

Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.

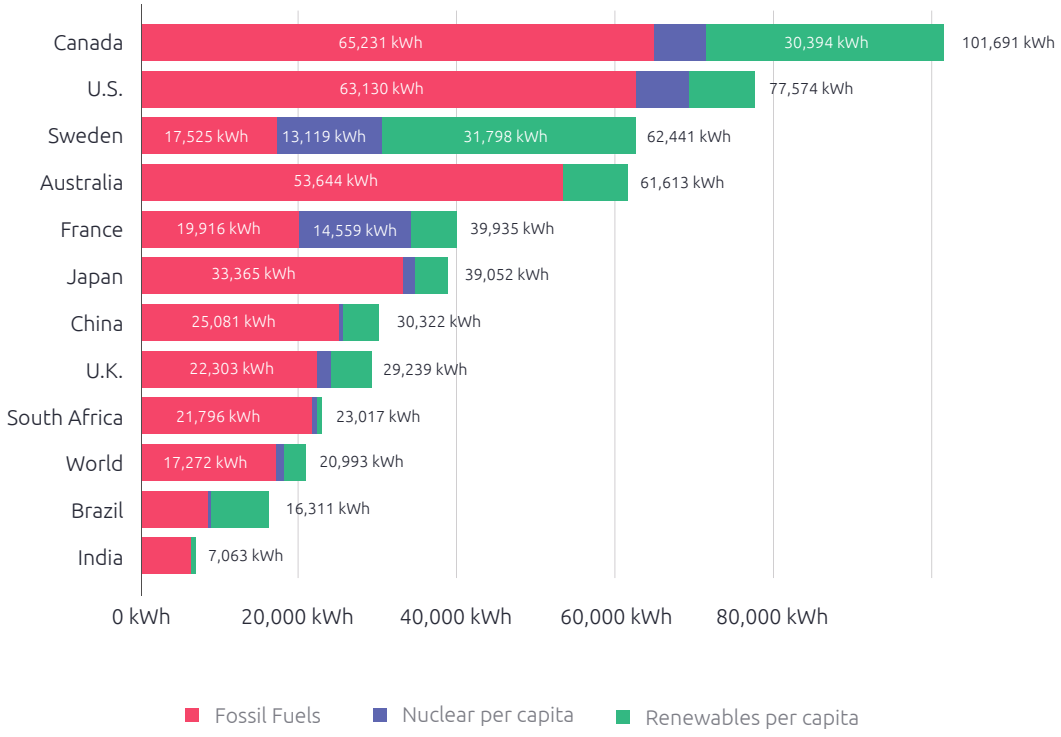
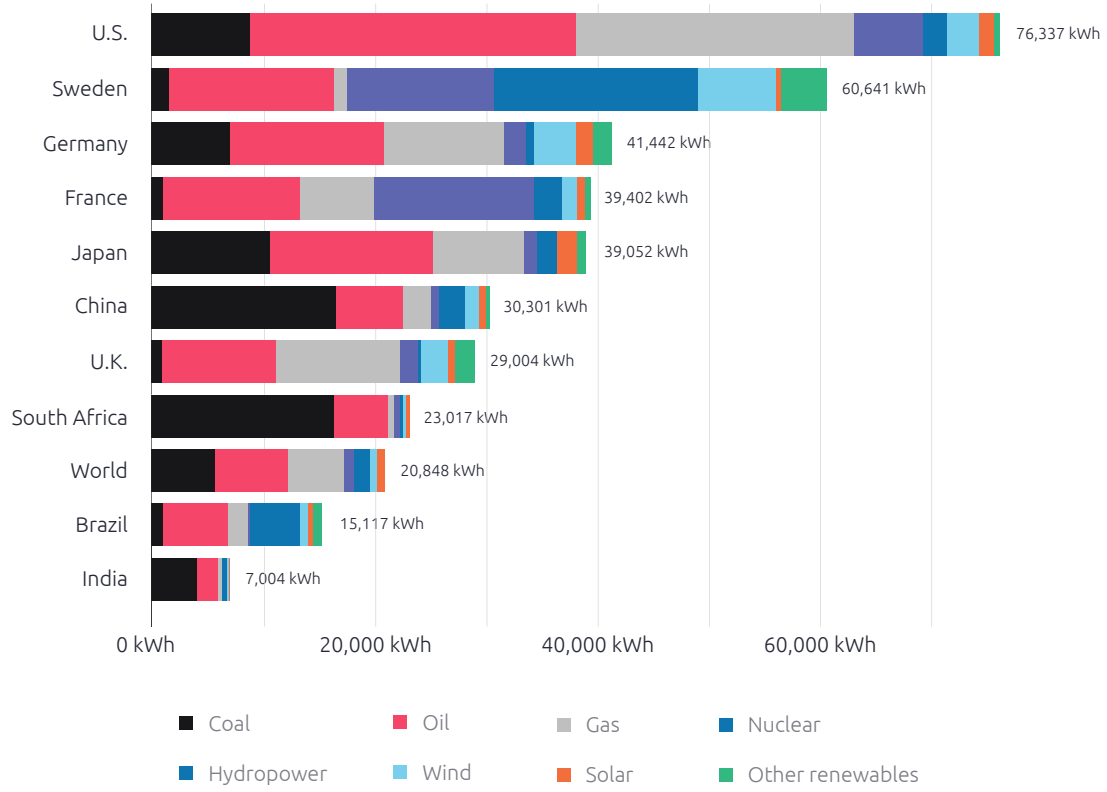


FIGURE 21

Per capita primary energy consumption by source, 2021

Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.



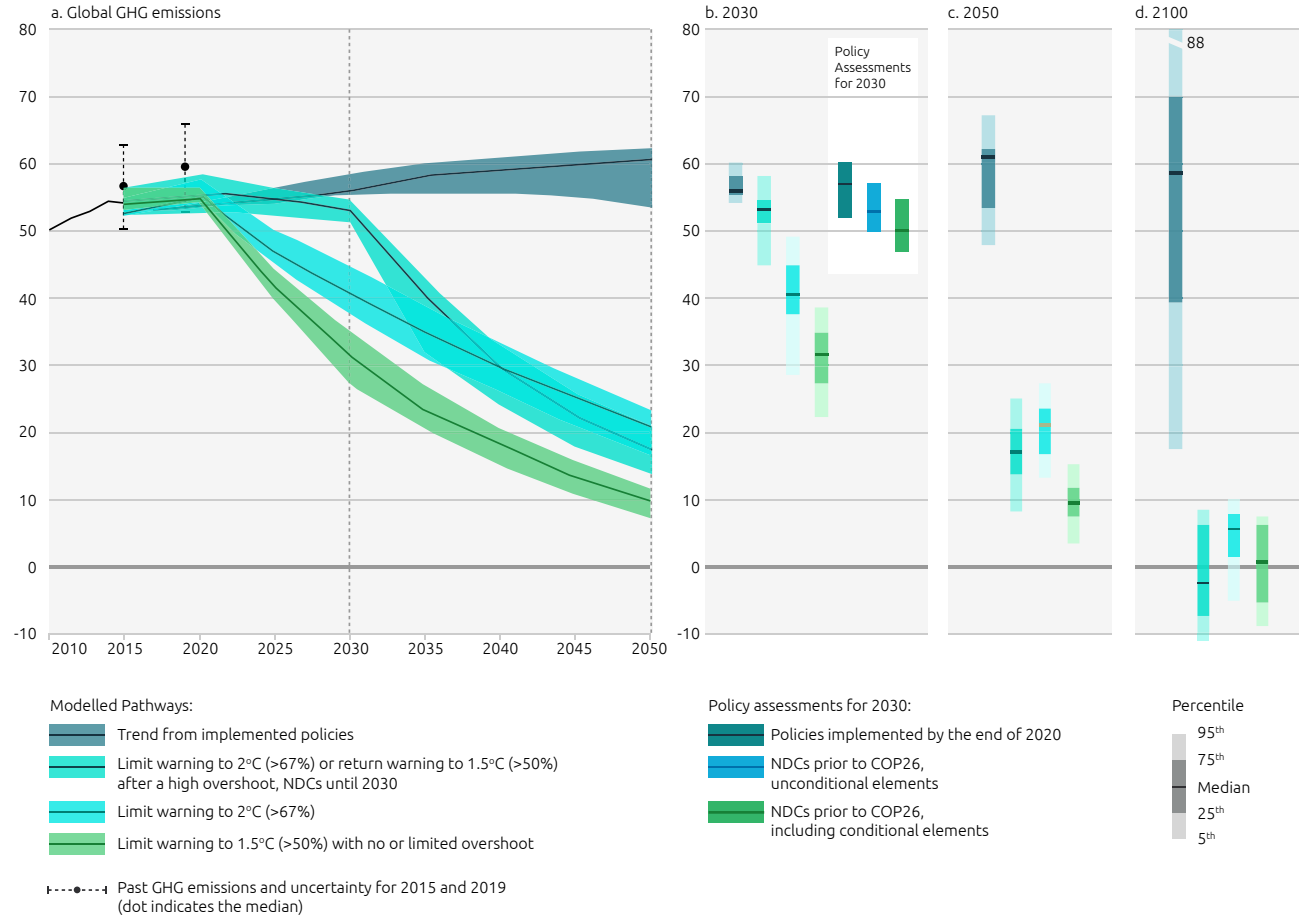
Source: https://ourworldindata.org/energy-mix

Drastic changes are required to reach the 1.5°C limit of the Paris Agreement

The current global response to climate change is insufficient to limit global warming to 1.5°C following the current trend of policies (as seen in dark blue in the chart). GHG emissions reduction must be accelerated to limit global warming to 1.5°C (green) and 2°C (light blue)[1].

FIGURE 22

Projected global GHG emissions from NDCs announced prior to COP26 would make it likely that warming will exceed 1.5°C and would also make it harder after 2023 to limit warming to below 2°C.

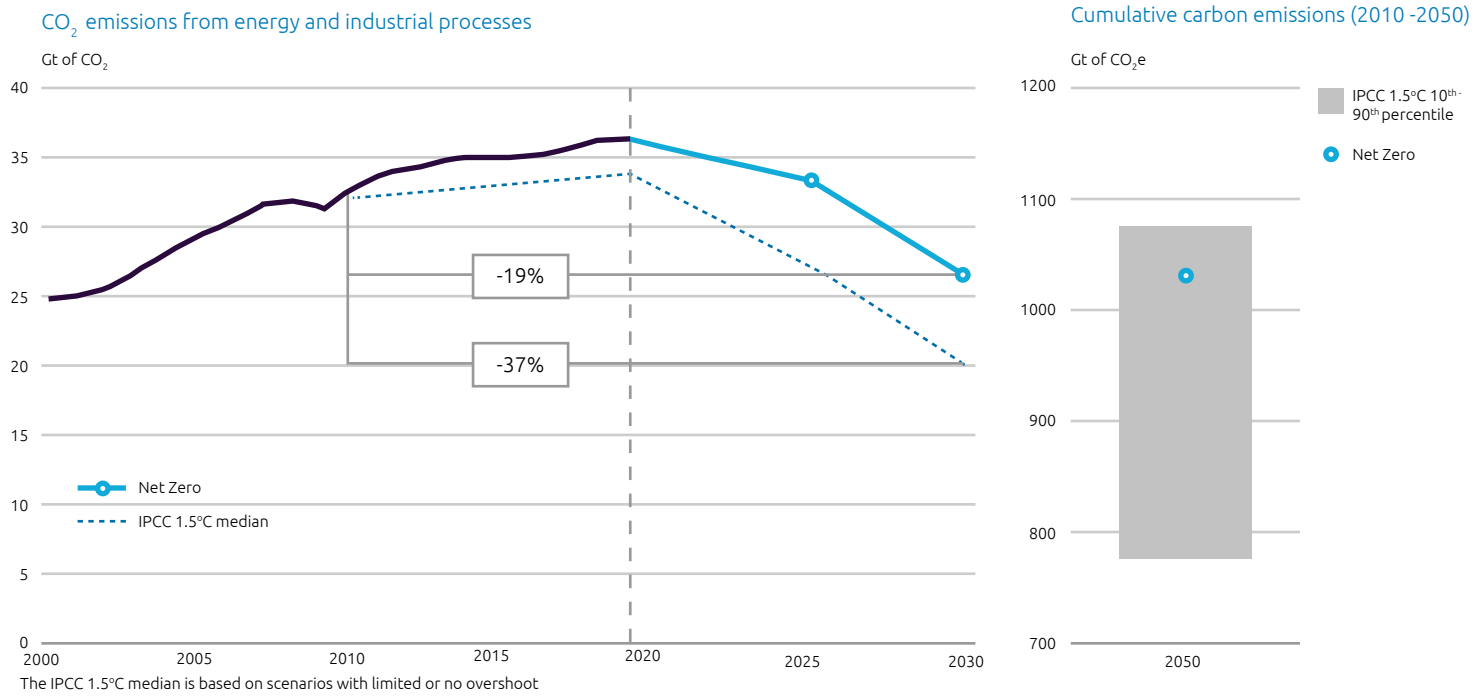


Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

1 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report.

FIGURE 23

Increased focus on speed of global decarbonization to 2030



The IPCC 1.5°C median is based on scenarios with limited or no overshoot

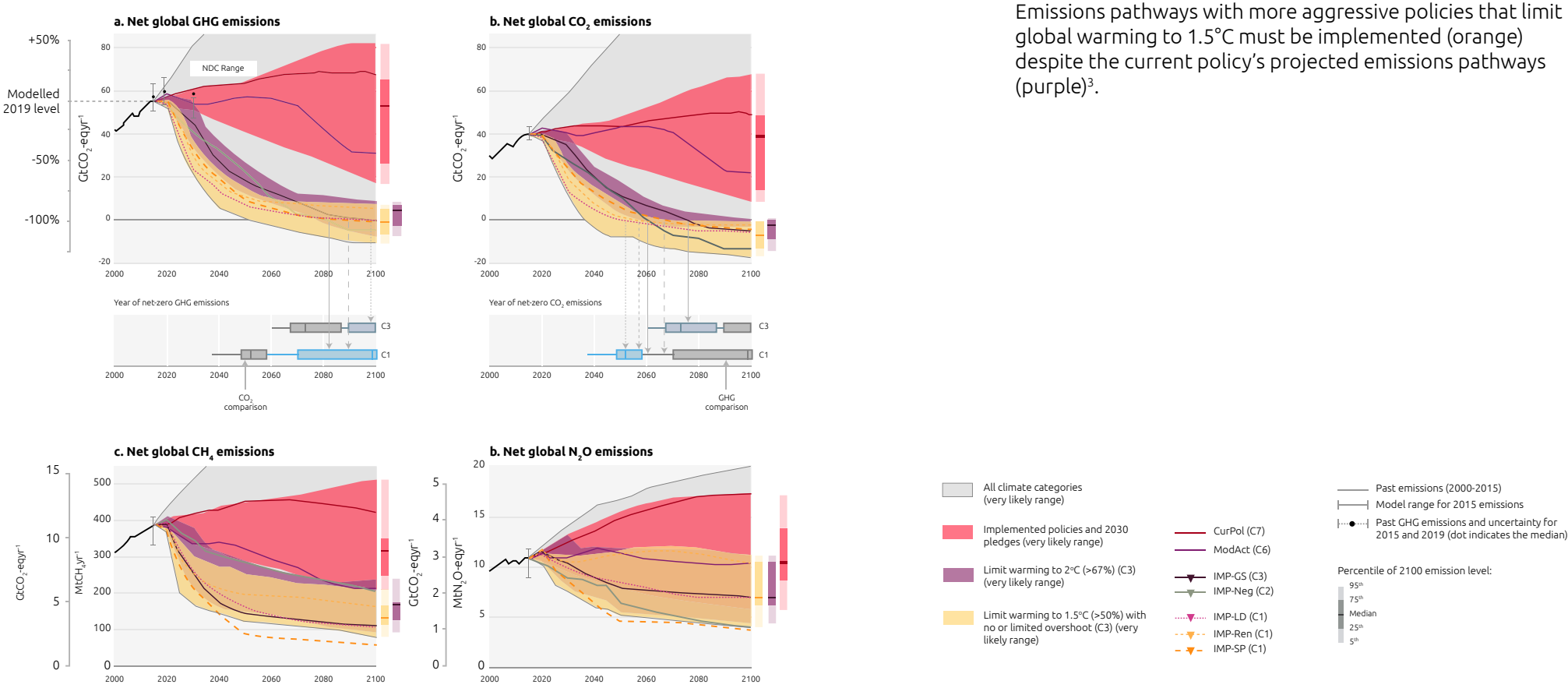
Source: EUROSTAT

To reach the 1.5°C climate goal the global net anthropogenic CO_2 emissions would need to decline by about 45% by 2030 (relative to 2010 levels). Considering that CO_2 emissions from fossil fuels and industry decrease by around 37% and 19% under a 2050 Net Zero scenario[2] (relative to 2010), is a must accelerate emissions reductions before 2030.

2 BP Energy Outlook 2022 report

FIGURE 24

Modelled mitigation pathways that limit warming to 1.5°C, and 2°C, involve deep, rapid and sustained emission reductions



Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

Pathways that limit global warming to 1.5°C or 2°C require immediate action and deep GHG emissions reductions, CO_2, methane (CH_4) and nitrous oxide (N_2O) across all sectors. Emissions pathways with more aggressive policies that limit global warming to 1.5°C must be implemented (orange) despite the current policy's projected emissions pathways (purple)[3].

3 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report.

Fossil fuels (coal, natural gas, and oil) made up nearly 77% of the world's energy supply in 2021 while low carbon technologies were just 23%[4] and 12%[5] considering renewables sources.

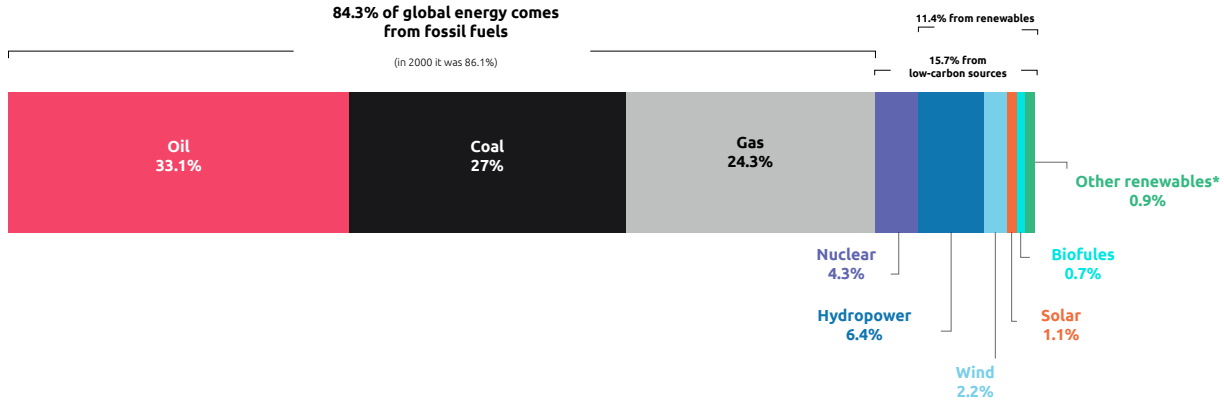
For the first time, the IEA foresees a peak in oil demand in all its scenarios in the mid-2030s. The SPS forecast shows a very gradual decline. And in the NZE forecast, it plateaus within a decade and drops further by nearly three-quarters by 2050[6].

To limit the rise to 1.5°C, the IEA's Net Zero Emissions by 2050 prediction envisions those fossil fuels shrinking to just under a quarter of the mid-century supply mix with renewables skyrocketing to just over two-thirds[7].

FIGURE 25

Global primary energy consumption by source

The breakdown of primary energy is shown based on the 'substitution' method which takes account of the inefficiencies in energy production from fossil fuels. This is based on global energy for 2019.



*'Other renewables' includes geothermal, biomass, wave and tidal. It does not include traditional biomass which can be a key energy source in lower income settings.
OurWorldInData.org - Research and data to make progress against the world's largest problems.

Source: BP's Statistical Review of World Energy.

4 BP Statistical Review of World Energy (including solar, wind, hydropower, other renewables, nuclear, biofuels and biomass energy)
5 BP Statistical Review of World Energy (including solar, wind, hydropower, and other renewables)

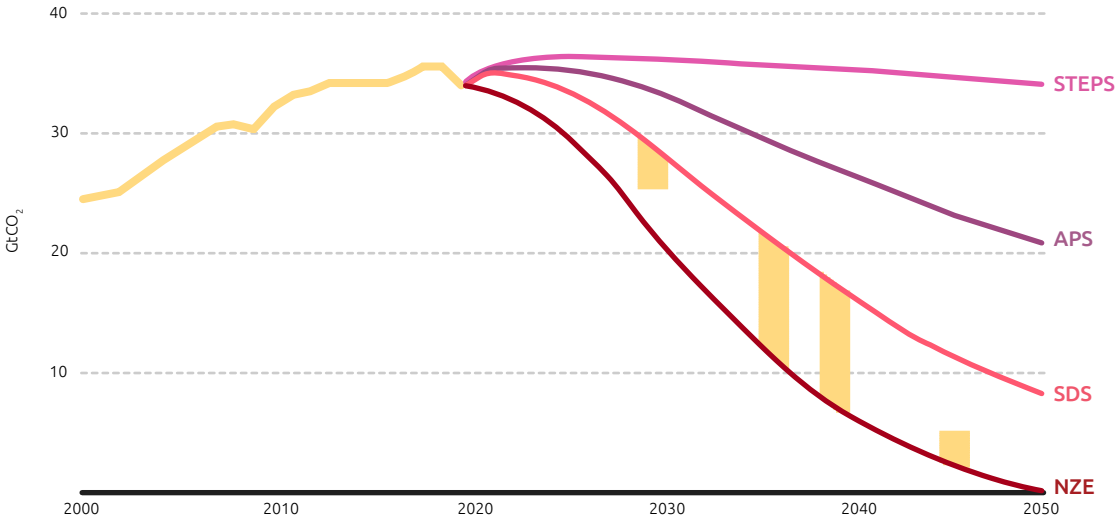
6 IEA World Energy Outlook 2021 report

7 IEA World Energy Outlook 2021 report

Following chart shows carbon dioxide emissions in the World Energy Outlook 2021 under 4 different scenarios over time[8]: Announced Pledges Scenario (APS)[9], Net Zero Emissions by 2050 Scenario (NZE)[10], Stated Policies Scenario (STEPS)[11] and Sustainable Development Scenario (SDS)[12].

FIGURE 26

Carbon dioxide emissions in World Energy Outlook 2021 scenarios over time



The APS pushes the emissions down, but not until after 2030; the SDS goes further and faster to be aligned with the Paris Agreement; the NZE delivers net zero emissions by 2050.

Source: IEA World Energy Outlook 2021 report

8 IEA World Energy Outlook 2021 report

9 Net Zero Emissions by 2050 Scenario: scenario which sets out a narrow but achievable pathway for the global energy sector to achieve net zero CO_2 emissions by 2050. It doesn't rely on emissions reductions from outside the energy sector to achieve its goals. To show what is needed across the main sectors by various actors, and by when, for the world to achieve net zero energy related and industrial process CO_2 emissions by 2050 while meeting other energy-related sustainable development goals.

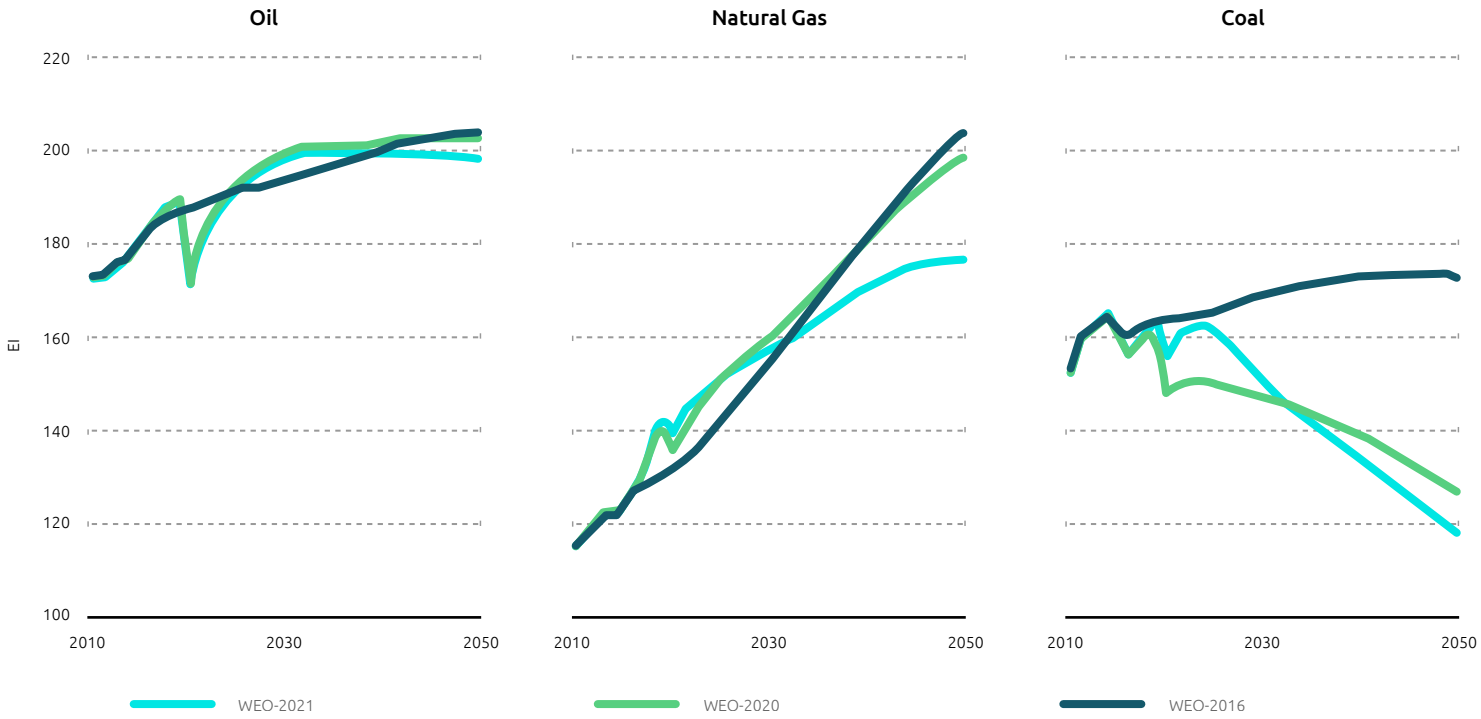
10 Announced Policies Scenario: scenario which assumes that all climate commitments made by governments around the world, including Nationally Determined Contributions (NDCs) and longer-term net zero targets, will be met in full and on time. To show how close do current pledges get the world towards the target of limiting global warming to 1.5 °C, it highlights the "ambition gap" that needs to be closed to achieve the goals agreed at Paris in 2015.

11 Stated Policies Scenario: scenario which reflects current policy settings based on a sector-by-sector assessment of the specific policies that are in place, as well as those that have been announced by governments around the world. To provide a benchmark to assess the potential achievements (and limitations) of recent developments in energy and climate policy.

12 Sustainable Development Scenario: integrated scenario specifying a pathway aiming at ensuring universal access to affordable, reliable, sustainable and modern energy services by 2030; substantially reducing air pollution; and taking effective action to combat climate change. To demonstrate a plausible path to concurrently achieve universal energy access, set a path towards meeting the objectives of the Paris Agreement on climate change and significantly reduce air pollution.

FIGURE 27

Comparison of oil, natural gas and coal demand in Stated Polices Scenario in World Energy Outlooks 2016, 2020 and 2021 over time



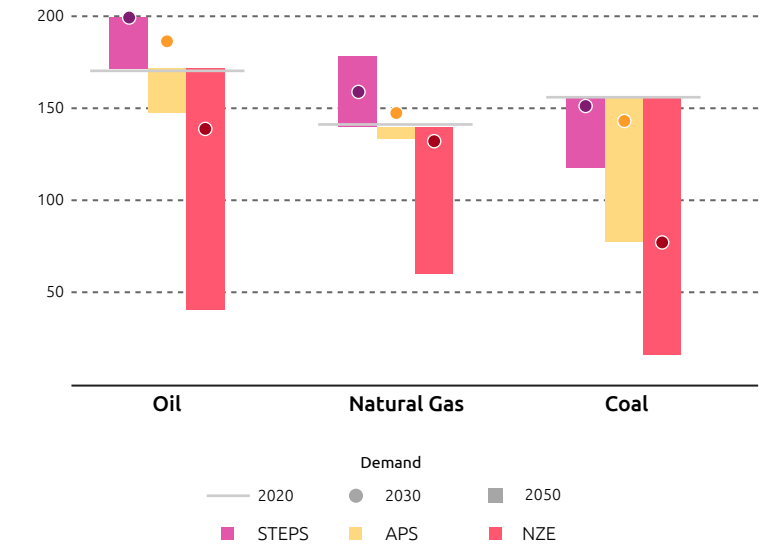
Oil demand peaks for the first time in the WEO-2021 steps; natural gas has been revised down from the WEO-2020; coal use is a lot lower than projected five years ago.

Source: IEA World Energy Outlook 2021 report

New oil fields are required in the two most conservative scenarios, and they would mitigate their climate impact by reducing methane flaring. Therefore, today's energy system cannot meet low emissions challenges[13]. Next chart shows fossil fuel use by STEPS, APS, and NZE scenarios by 2030 and 2050.

FIGURE 28

Fossil fuel use by STEPS (Stated Policies), APS (Announced Pledges) and NZE (Net Zero) scenarios by 2030 and 2050



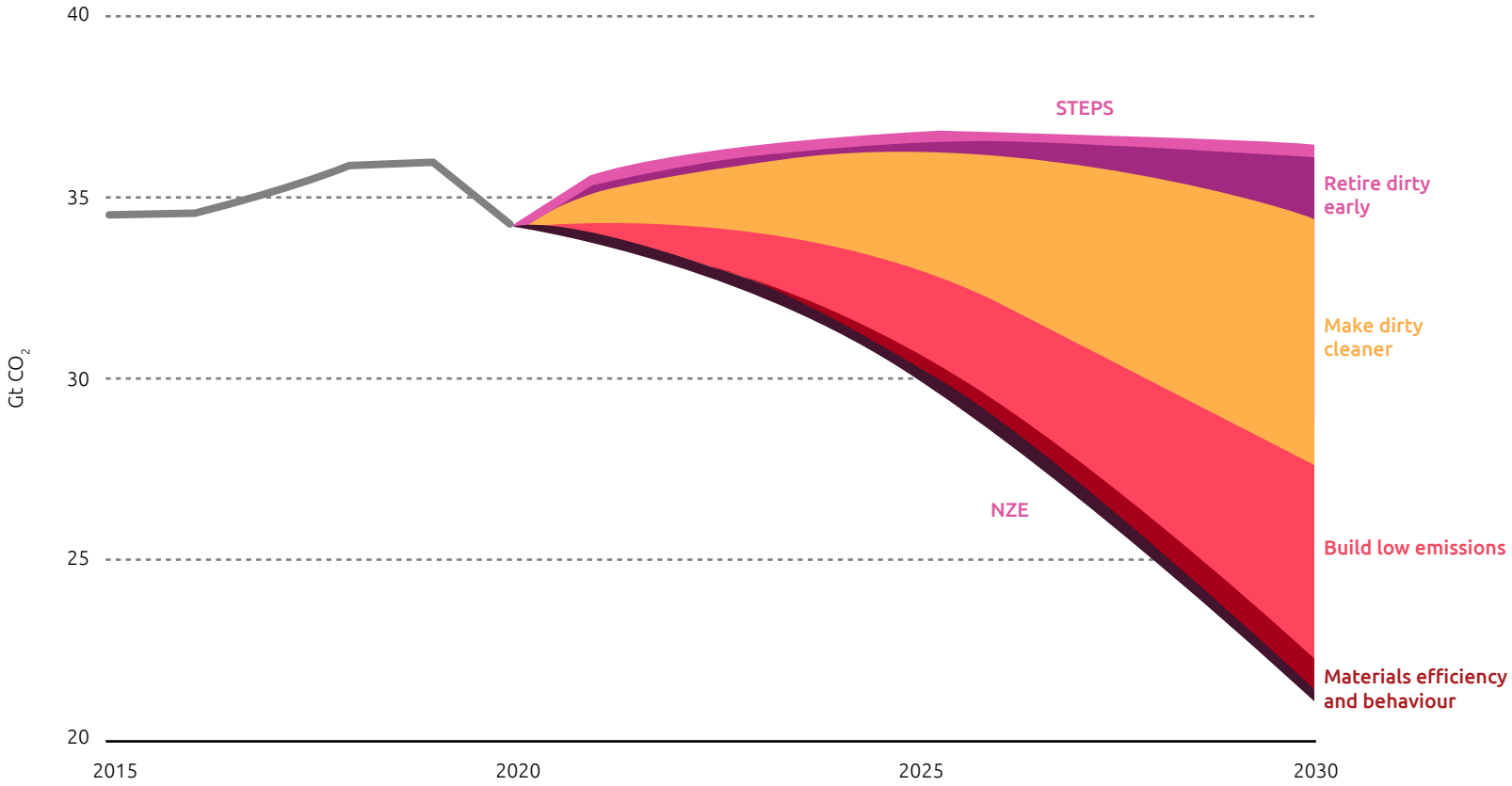
Oil demand peaks in each scenario, but the level and timing vary; natural gas increases to 2025 with sharp divergences thereafter; coal falls in all scenarios

Source: IEA World Energy Outlook 2021 report

13 IEA

FIGURE 29

Emissions reductions by 2050 in the NZE (Net Zero) and STEPS (Stated Policies) scenarios



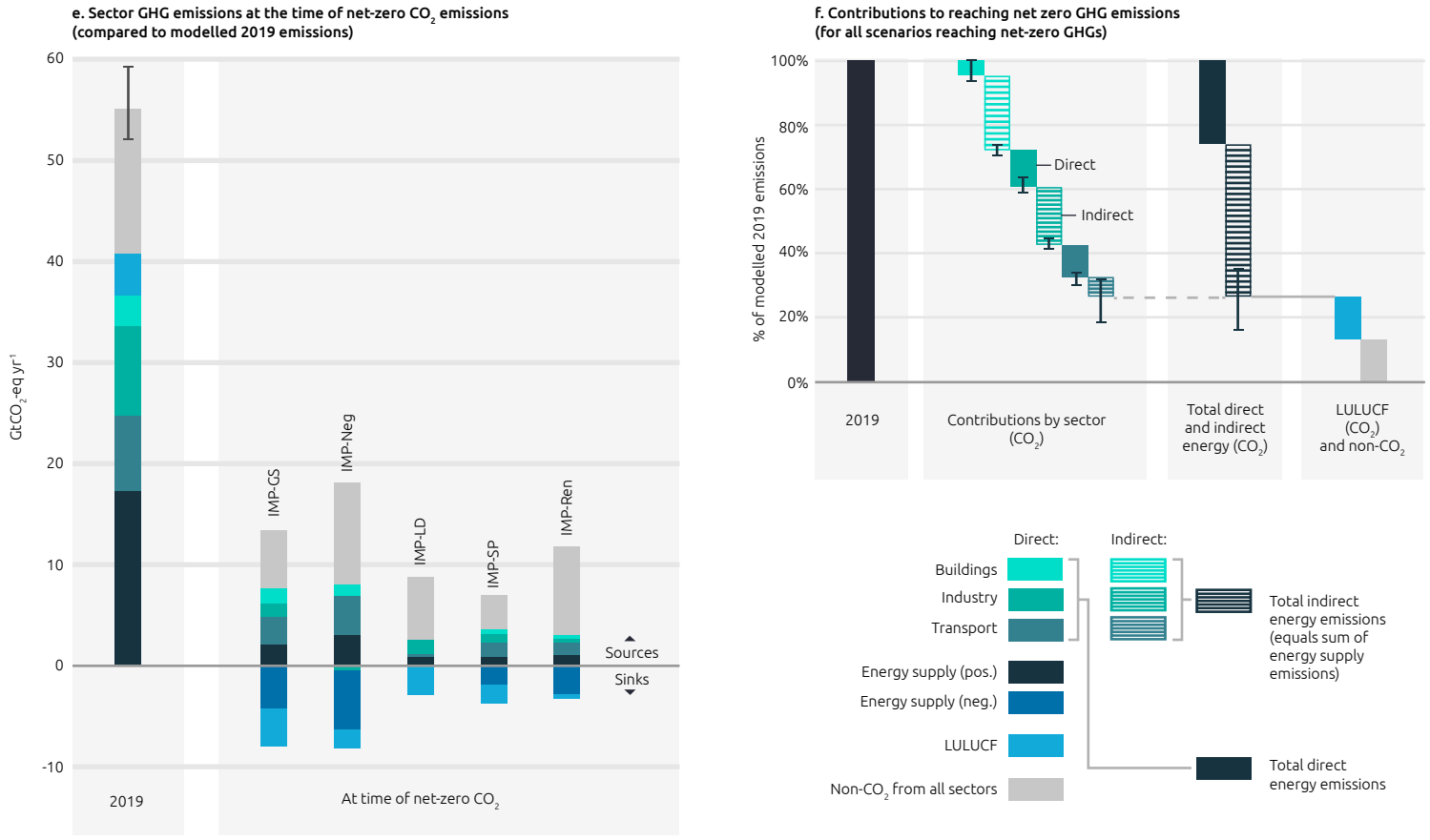
Delivering net zero requires more than retiring dirty and building low emissions projects; there is a large middle ground that defines the speed and scope of change

Source: IEA World Energy Outlook 2021

FIGURE 30

Carbon dioxide emissions come by 3 main sectors mostly: energy supply, transport and industry

Net zero CO_2 and GHG emissions are possible through different modelled mitigation pathways



Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

Today, in all sectors, many options are available to significantly decrease emissions by 2030, with several mitigation strategies. However, not all climate change solutions will have the same impact or cost[14].

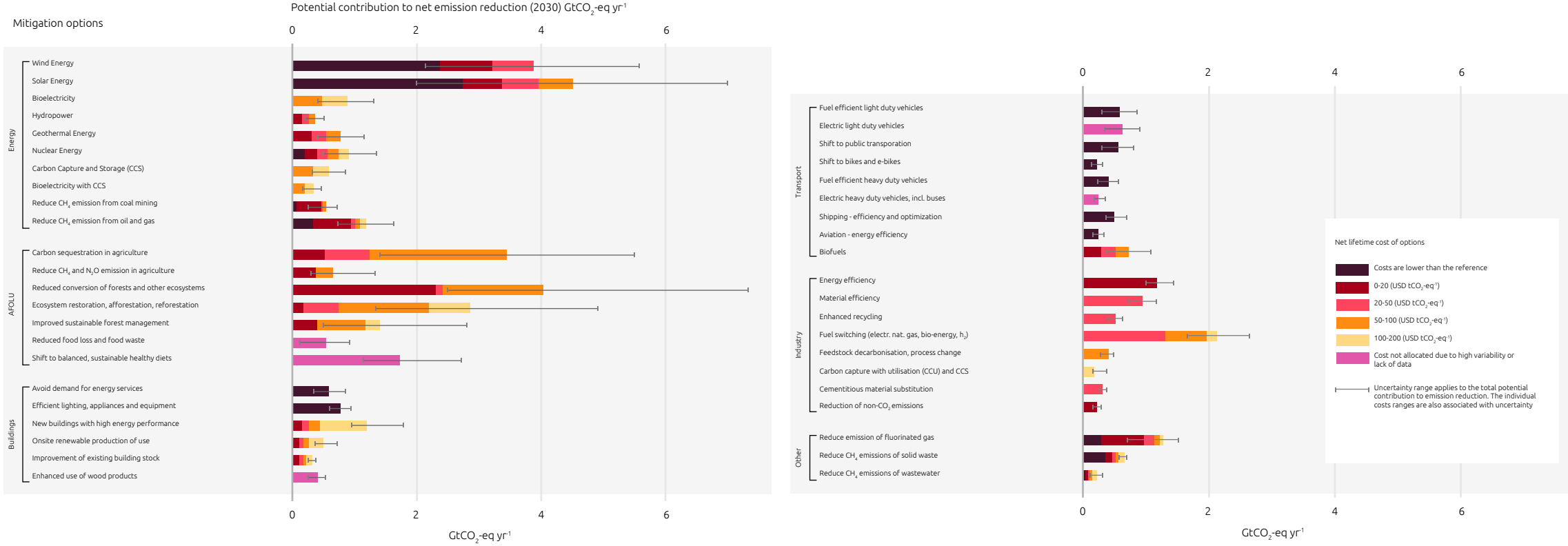
Climate change is not caused by one reason and won't be solved by one solution. It is caused by a group of issues and needs to be resolved by a group of mitigation actions. The mix of factors and solutions are all incremental, but the consequences of inaction are urgent and clear.

14 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report.

FIGURE 31

Mitigation options for net emission reduction by 2030

Many options available now in all sectors are estimated to offer substantial potential to reduce net emissions by 2030. Relative potentials and costs will vary across countries and in the longer term compared to 2030.



Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

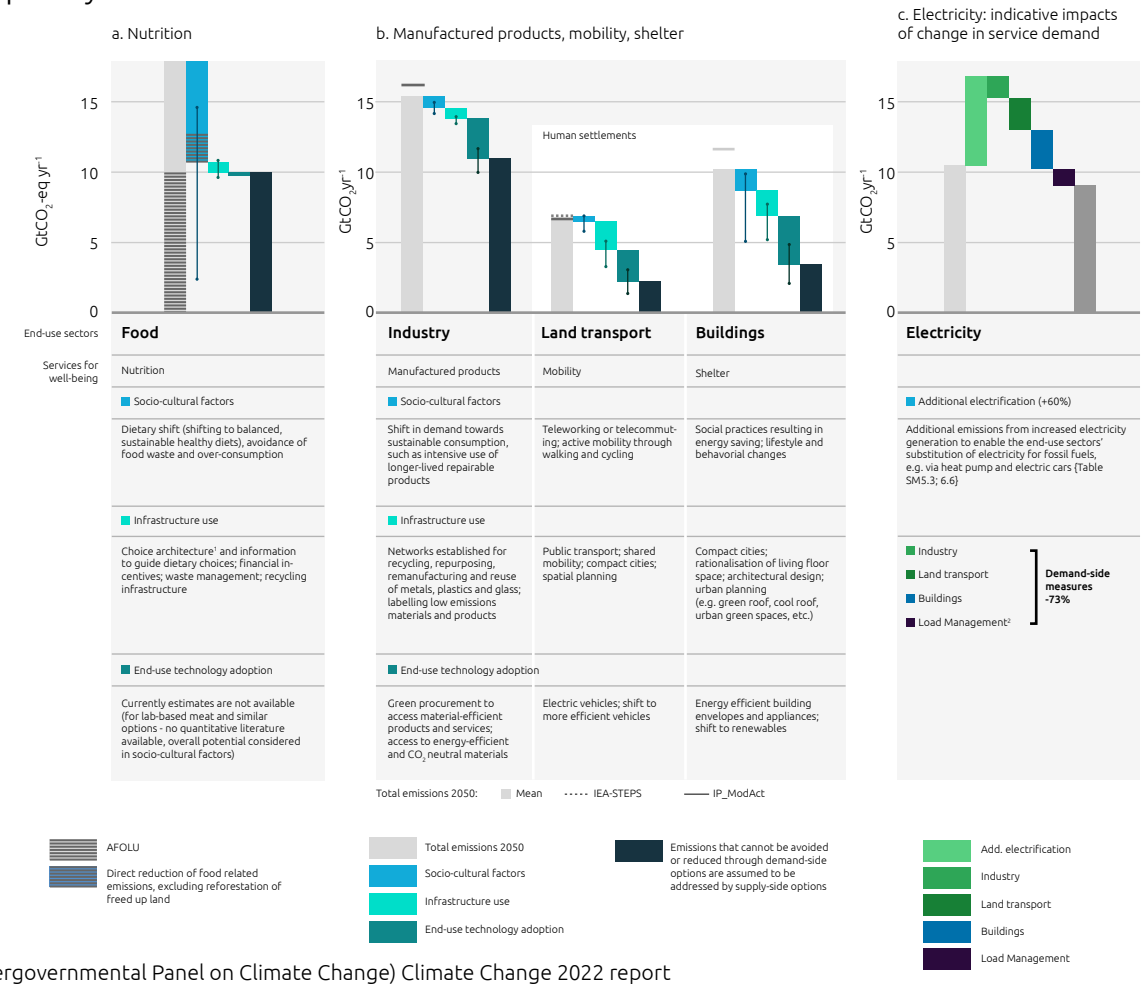
Efficiency savings and consumer behavior changes can lower demand. Climate change mitigation is affected by changing the demand for food, electricity, and manufactured products through infrastructure and behavioral adaptations. There are three ways to impart change: through socio-cultural factors (behavioral choices individuals make); through infrastructure use (changes in the design of the infrastructure that make it possible for individuals to make different choices); and through end-use technology adoption (changes in the uptake of technologies by end users)[15].

Countries and economic stakeholders must decide on and implement national and local causes for consumption reduction and energy efficiency. Traveling less and eating less meat are among a long list of possible actions. Of course, public administration should show the way (like some companies are doing or have started to do) with transportation electrification, building refurbishment for energy efficiency, and many other actions. This also means subsidizing the development and appropriation of low-carbon technologies and growing infrastructures (EV charging networks, smart grids, and H_2 networks, notably).

Having the right infrastructure and technology policies will enable lifestyle and behavior changes and result in a 40-70% reduction in GHG emissions by 2050. This offers significant untapped potential in improving health and well-being.

FIGURE 32

Demand-side mitigation can be achieved through changes in socio-cultural factors, infrastructure design and use, and end-use technology adoption by 2050



Source: IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report

15 IPCC (Intergovernmental Panel on Climate Change) Climate Change 2022 report.

The most urgent priorities should strive to put energy transition on track to the 1.5°C goal[16]:

- Resolutely replacing coal power with clean alternatives, i.e., renewable sources. Replacing coal in industry must also be tackled, as almost 30% of all coal is used in iron, steel, cement, and other industries. In the power sector, renewables are three times faster and cheaper than the current deployment rate.
- Ramping up renewables with an aggressive energy efficiency strategy is the most realistic path toward halving emissions by 2030.
- Phasing out fossil fuel assets should be done in tandem with measures to eliminate market distortions and incentivize energy transition solutions supported with storage options and or another low carbon sources guarantying the supply. This will ensure the full cost (environmental, health, and social) of burning fossil fuels is reflected in their prices, eliminating existing market distortions.
- Securing nuclear power development with present technologies (long cycle projects) and promising ones (small modular reactors (SMR) and fusion) is required for net zero targets but will be more for the 2030s-2050s.

16 IRENA World Energy Transitions Outlook 2022 report

Recommendations and Actions

The world has a huge challenge to move a net zero economy by 2050 from a narrow possibility to urgent actions comes to a reality, now doubly urgent and complex due to the emissions rebounding sharply after pandemic and geopolitical situation, time is over and act urgently to accelerate the clean energy transformation must be our highest priority as human beings.

Despite some progress, the energy transition is far from being on track, and radical actions is needed to change current trajectory, and to achieve the 2050 net zero target depends on today actions where coming years will be critical for accelerating the energy transition up to 2030 reaching a crucial moment for international efforts to tackle the climate crisis.

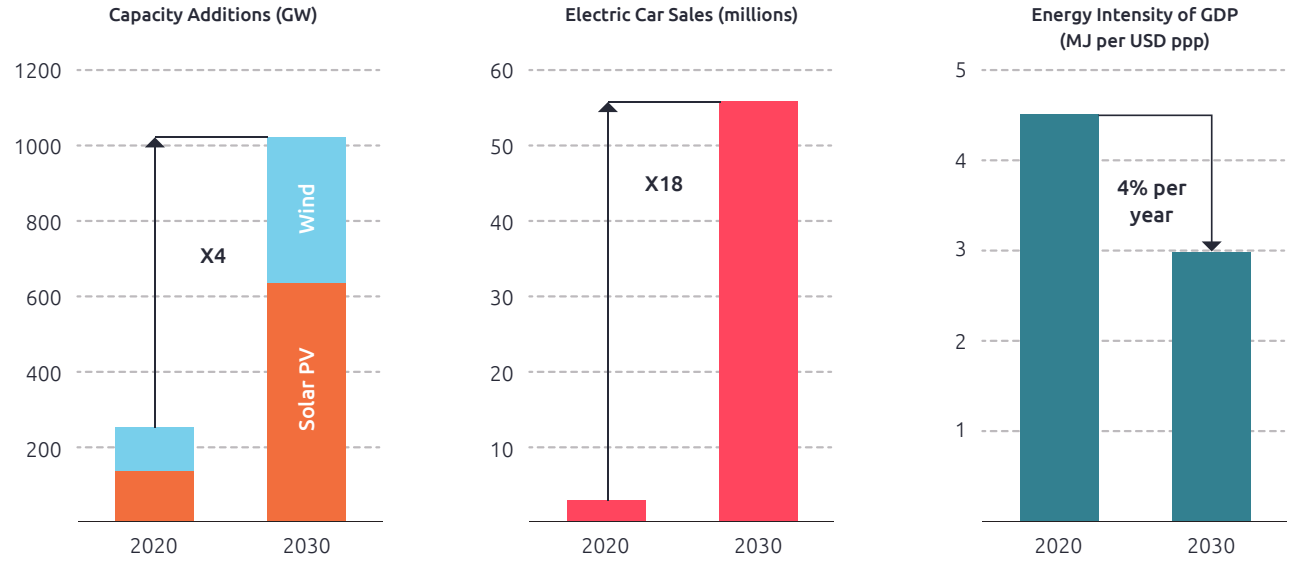
The number of countries that have pledged to reach net zero emissions by 2050-or soon after is growing, but the gap between rhetoric pledges and actions need to close if we want to limit the global warming to 1.5 °C requiring from now on a total transformation of the energy systems and our economies.

Energy transition actions and the way to reach net zero emissions economies have to be guided by several principles[1]:

- secure and affordable energy supplies to foster economic growth with a huge opportunity for boost economic growth, creating millions of new jobs.
- transparent, fair and inclusive, leaving nobody behind. Developing economies need to receive the financing and technological know how needed for those expanding populations and economies in a sustainable way.
- is about people and centered in people along the entire process changing habits in final consumers, specially from power, industry, and transport, including lifestyle and consumption shifts.
- each country will need to review and improve actual actions, accelerating its own pathway according to its own specific circumstances. There is no one single magic action for all.

FIGURE 33

Key clean technologies ramp up by 2030 in the net zero pathway



Note: MJ = megajoules; GDP = Gross Domestic Product in purchasing power parity.

Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

1 IEA Net Zero by 2050-Roadmap

Urgent recommendations and actions today, not tomorrow

Massive clean energy expansion and an unparalleled clean energy investment boom from today accelerating the current paths increasing ambition by 2030. World is in a 2.7°C warming track far from the limit to 1.5°C leaded by bigger economies, and all technologies needed already exist.

World leaders, countries, businesses and people must shift the gear and accelerate in the right direction.

A transition of the scale and speed to reach a net zero pathway cannot be achieved without sustained support and participation from citizens affecting of people's lives in demand for energy services from transport, heating and cooking to urban planning and jobs. Behavioral changes, particularly in advanced economies such as replacing car trips with walking, cycling or public transport, or foregoing a long-haul flight.

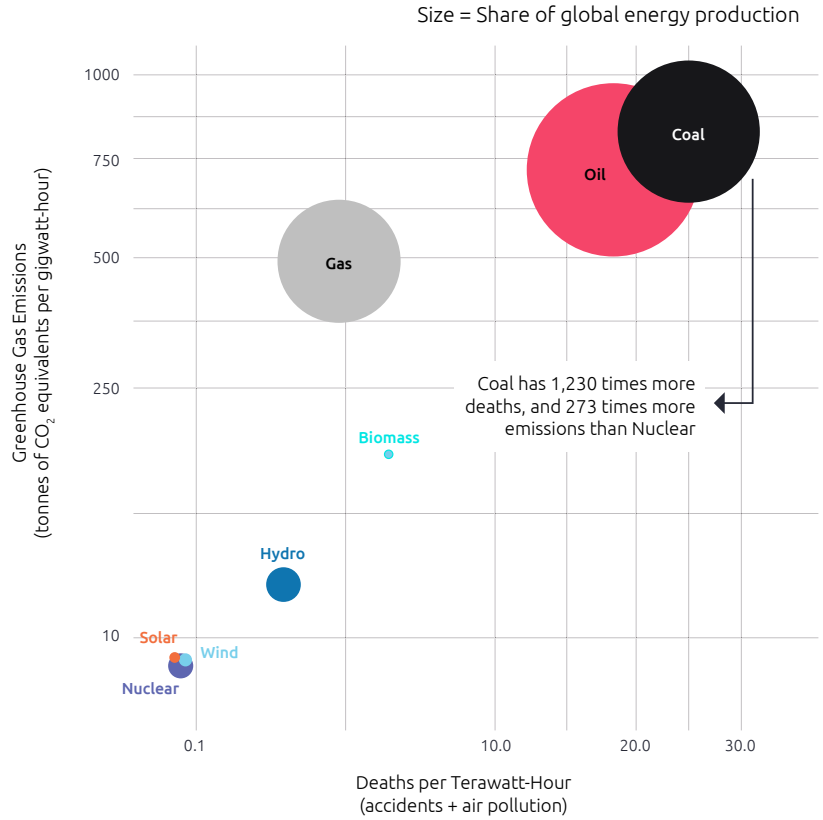
The rapid electrification of all sectors makes electricity even more central to energy security around the world than it is today. Electricity from renewables sources (solar, wind, and hydro mostly) together nuclear power plants as main low-carbon technologies becomes the primary energy carrier in future energy systems[2]:

- Global electricity demand in end-use sectors will rise 1.3 times the 2019 levels to reach Ca.31,000 TWh by 2030.
- The share of electrification in end-use sectors like industry, buildings, and transport would reach 28%, 56%, and 9% in 2030, respectively.

Today's technologies with lower GHG emissions and lower death rates from accidents and air pollution are solar, wind, nuclear and hydropower:

FIGURE 34

US EV Sales and Sales Share Forecast 2021-2030



Source: Our World In Data, 2020. Square root scales for x and y axes. Graph by: @rubenbmathisen (Twitter)

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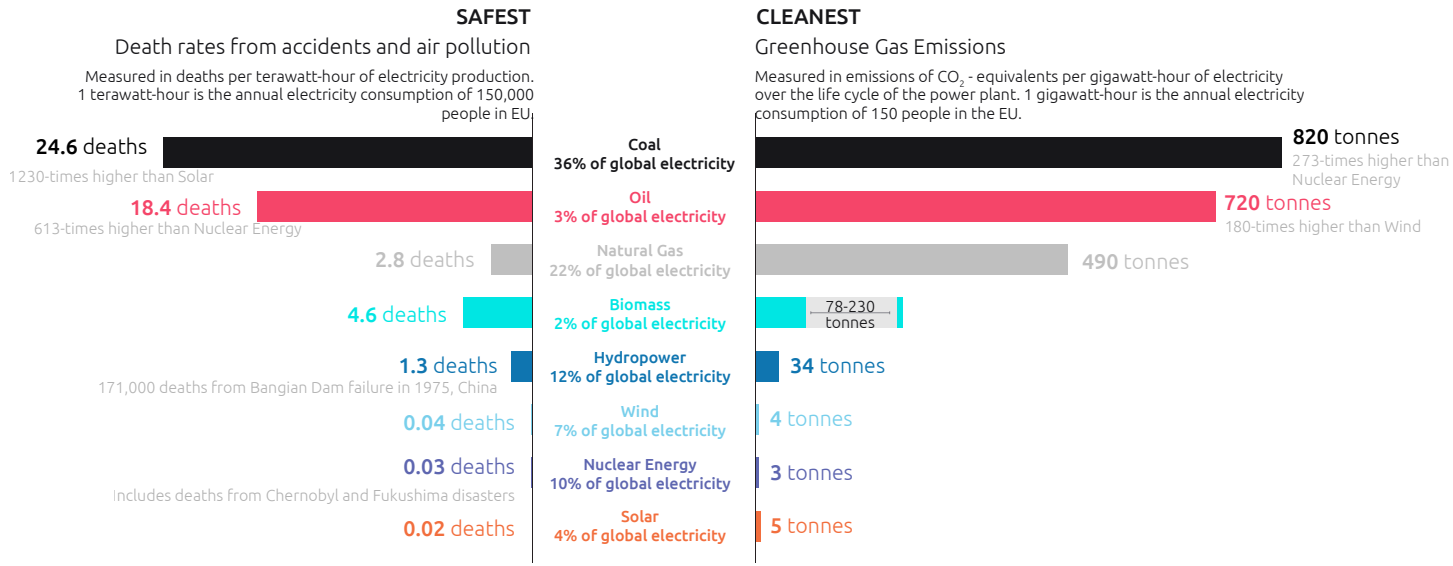
FIGURE 35

What are the safest and cleanest sources of energy?



Death rates from fossil fuels and biomass are based on state of the art plants with pollution control in Europe, and are based on older models of the impacts of air pollution on health. This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.

Source: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC ARS (2014); Pehl et al. (2017); Ember Energy (2021).

Policies should be strengthened to speed up the deployment of clean and efficient energy technologies driving investments into the most efficient ones.

Infrastructure upgrades, modernization, and expansion are needed to increase system resilience and build flexibility for a diversified and interconnected system capable of accommodating high shares of variable renewable energy.

Governments must lead the planning and incentivizing of the massive infrastructure investments, especially in smart transmission and distribution grids expanding annual investment in T&D grids from USD 260 billion today to USD 820 billion in 2030, number of public charging points for EVs rises from around 1 million today to 40 million in 2030, battery production for EVs leaps from 160 GWh today to 6 600 GWh in 2030 equivalent of adding almost 20 giga factories.

The transition needs all major sources of flexibility options: batteries, demand response and a smarter and more digital electricity networks. The resilience of electricity systems to cyberattacks and other emerging threats needs to be enhanced. Transition will be green and digital, or won't be.

Green jobs will grow bringing substantial new economic opportunities for wealthiness and employment, with at least new 14 million jobs created by 2030.

Energy transition will require significant quantities of critical minerals, like copper, cobalt, manganese, lithium, and various rare earth metals creating new economic opportunities and no dependance of one or a very few countries. The quantities required will be multipled by a factor of 16 by 2050. Renewables technologies require a huge intensity of critical minerals per energy unit produced in comparison with low carbon technologies like nuclear, around 6 times more, and specially this difference many times higher considering the total critical minerals amount to reach the net zero goal.

Roll-out of hydrogen, CCUS, and even DAC technologies after 2030, currently all of them making remarkable progresses, means laying the groundwork now with annual investment in CO2 pipelines and hydrogen enabling infrastructure increases from USD 1 billion today to around USD 40 billion in 2030, and where hydrogen and CCUS.

No new investments in new fossil fuel power plants, no new coal mines or mine extensions, natural gas as bridge as minim as possible to guarantee security supply to be substituted by clean sources, and subsidy phase-outs.

Policymakers should identify priorities for electrification with a focus on hard-to-abate sectors and devise strategies for its deployment. and disincentive for the use of certain fuels and technologies, such as unabated coal-fired power stations, gas boilers and conventional internal combustion engine vehicles.

Oil and natural gas production will have far-reaching implications specially under current geopolitical circumstances and energy crisis. No new oil and natural gas fields are needed but current are necessary to bridge the transition, and structural reforms to carry out the transition and journey as quick as possible to technologies such as storage, hydrogen, CCUS, DAC, demand response and low-carbon flexible power plants.

Carbon pricing mechanisms and market reforms can ensure appropriate price signals to speed up the right and accelerated transition.

Set near-term milestones to get on track for long-term targets providing credible step-by-step plans to reach net zero goals, building confidence among investors, industry, citizens and other countries.

FIGURE 36

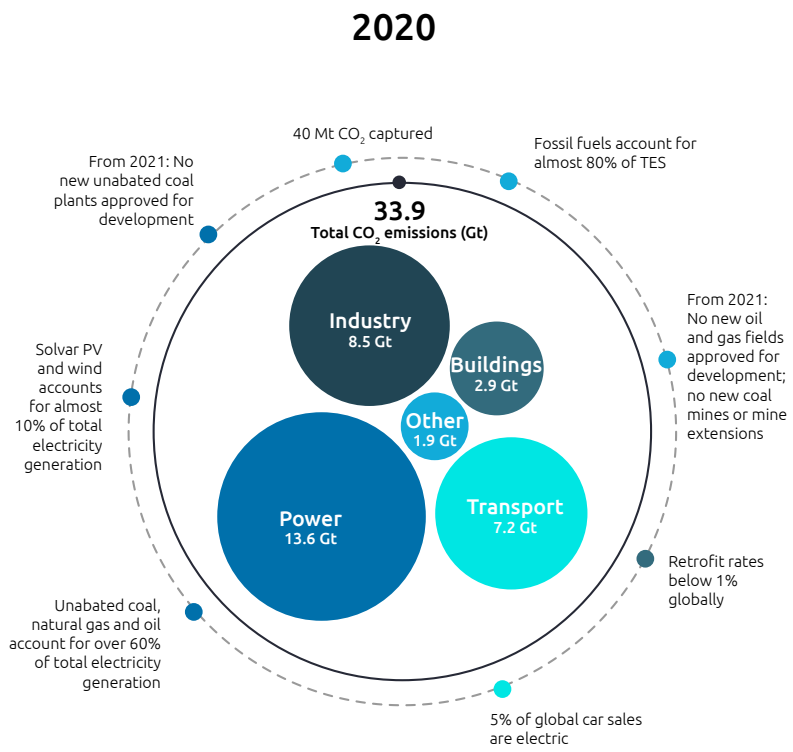
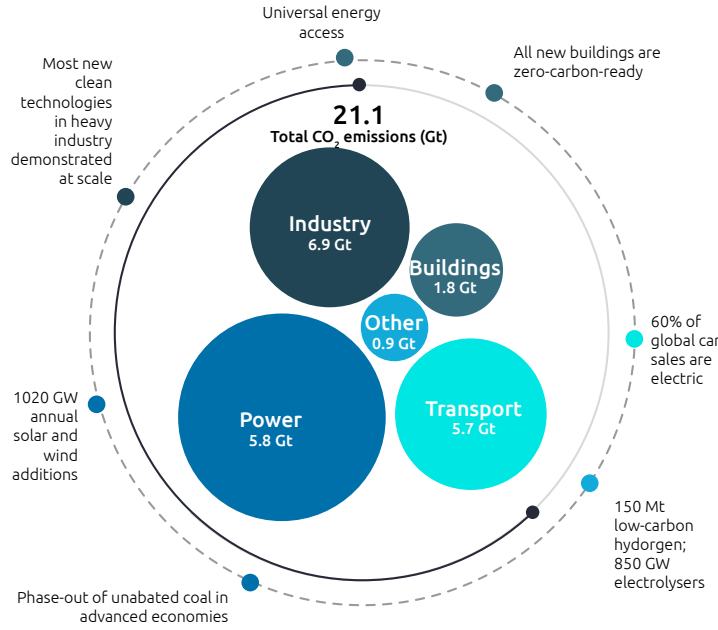


FIGURE 37



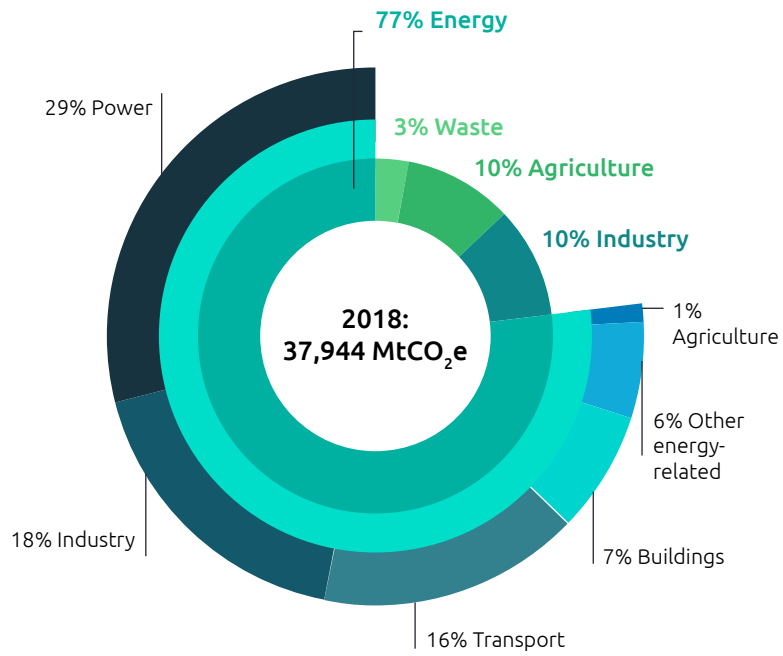
Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

Key milestones and actions for rapid emission reductions[3]:

- Ramping up renewables and an aggressive energy efficiency strategy is the most realistic path toward halving emissions by 2030. This also means adapting grids (smart grids).
- Scaling up solar and wind rapidly for this decade, reaching annual additions of 630 GW of solar PV and 390 GW of wind by 2030, four-times the record levels set in 2020. For solar PV, this is equivalent to installing the world's current largest solar park roughly every day.
- Hydropower and nuclear, the two largest sources of low-carbon electricity today, will be essential for transition.
- New buildings must be energy efficient, decarbonizing heating and cooling will require changes to building codes and energy performance standards using renewables-based heating and cooling technologies, solar water heaters, renewables-based heat pumps, and geothermal heating.
- Electric vehicles (EVs) go from around 5% of global car sales to more than 60% by 2030.
- Land use measures to curb the loss of forest areas and encourage replanting.
- Demand-side management would help alleviate multiple challenges in the short term while contributing to the long-term security of energy and materials supply.

FIGURE 38

G20 GHG emissions by sector (2018)



Source: The Climate Transparency Report 2021

Accelerated deployment of green hydrogen and sustainable biomass are key solutions to decarbonize hard-to-abate sectors while also contributing to energy security[4]:

- Green hydrogen should move from niche to mainstream by 2030. In 2021, only 0.5 GW of electrolyzers were installed; cumulative installed capacity would need to grow to 350 GW by 2030 what looks like a great challenge considering current status and lack of infrastructures. Coming years should bring relevant actions to develop the global market and reduce costs with specific support schemes and policies by Governments to reach long term goals.
- Modern bioenergy's contribution to meet energy demand, including demand for feedstock, will have to triple by 2030. At the same time, the traditional use of biomass (such as firewood) needs to be replaced by clean cooking solutions.

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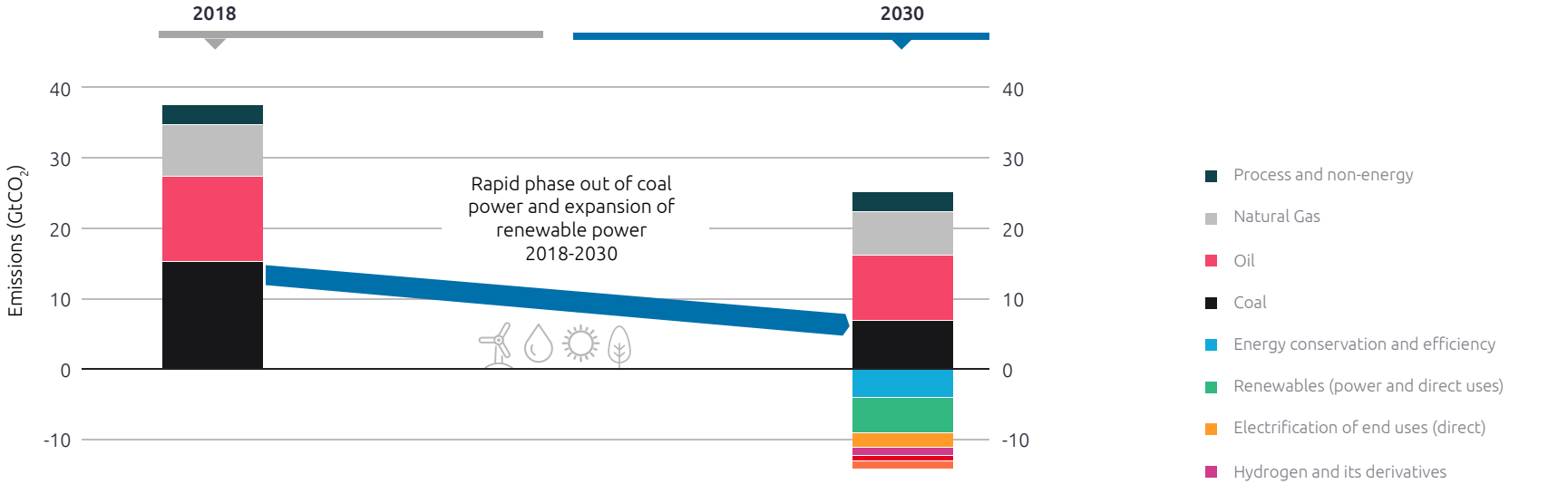
FIGURE 39

Emissions reductions 2018-2030



Renewable energy share in electricity generation must increase to 65% by 2030.

- And additional 8000 GW of renewable capacity in this decade.
- Installed capacity of onshore wind of 3000 GW, four times that of 2020.
- Offshore wind to scale up to 380 GW, 11 times more than in 2020.
- Installed capacity of solar PV to reach 5200 GW, 30% more than in 2020.
- Other renewable technologies to reach 750 GW, up six-fold from 2020.

The share of direct electricity in total final energy consumption (TFEC) must rise from 21% to 30%; deployment of energy efficiency measures must increase 2.5 times.

- A drop in TFEC from ca. 390 EJ today to 370 EJ.
- Expanded electrification of energy services, especially in transport sector.
- Improved energy efficiency standards and retrofitting of existing buildings.
- Process changes in industry, relocation of industries, and circular economy practices.

Direct renewables in end use sectors must grow from 12% in 2019 to 19% by 2030.

- Hydrogen consumption to reach a minimum of 19 EJ by 2030.
- Total consumption of bioenergy and feedstock in industry to increase to 25 EJ. 2.5 times more than in 2019.
- Solar thermal, geothermal and district heating solutions to be scaled up to 60 EJ, 1.3 times the 2019 levels.
- Biofuel's share for energy consumption in transport to increase from 3% in 2019 to 13%.
- Increase ambition on biojet to reach 20% of total fuel consumption by 2030.

Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

Net zero pathway by 2050

Electrification and efficiency are key drivers of the energy transition, enabled by renewables, hydrogen, and sustainable technologies, and a massive change in how produce and consume energy, would result in a cut of nearly 37 gigatonnes of annual CO2 emissions by 2050. These reductions can be achieved through:

- scale up generation and direct uses based on renewables-electricity sou rces.
- significant increase in energy efficiency measures.
- electrification of end-use (EV, heat pumps, etc.).
- green hydrogen and its derivatives.
- nuclear renaissance in some countries, acceleration in others.
- bioenergy coupled with CCS.
- last-mile use of carbon capture and storage.
- storage, smart grids and flexibility.

Energy sector shall be based largely on renewable energy sources with two-thirds of total energy supply in 2050 from wind, solar, bioenergy, geothermal and hydro energy, and being solar the largest source accounting for one-fifth of supplies. Solar PV capacity will have to increase 20-fold from now to 2050, and wind power 11-fold.

Net zero means a huge decline in the use of fossil fuels that shall remain in 2050 used in goods where the carbon is embodied in the product such as plastics, in facilities fitted with CCUS, and in sectors where low-emissions technology options are scarce.

Electricity accounts for almost 50% of total energy consumption in 2050. It plays a key role across all sectors from transport and buildings to industry, and is essential to produce low emissions fuels such as hydrogen. To achieve this, total electricity generation increases over two-and-a-half-times from today to 2050. By 2050, almost 90% of electricity generation shall come from renewable sources, with wind and solar PV together accounting for nearly 70% and most of the remainder will come from nuclear.

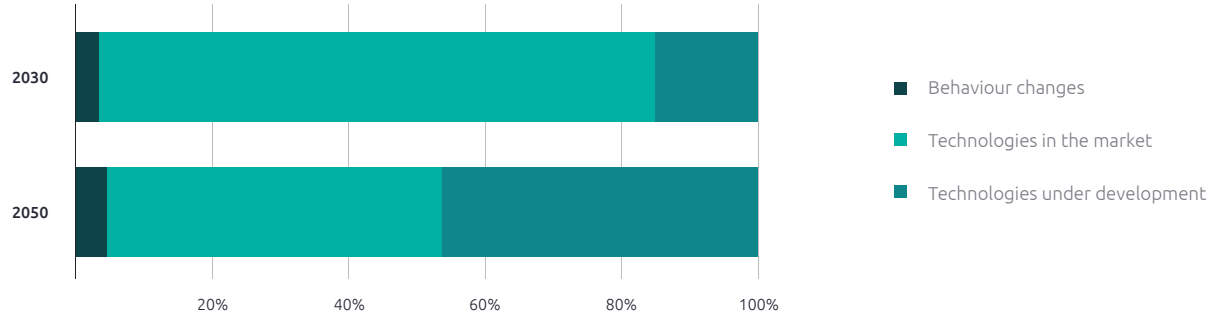
Emissions from industry, transport and buildings take longer to reduce. Cutting industry emissions by 95% by 2050 involves major efforts to build new infrastructure through R&D and initial deployment between now and 2030 to bring new clean technologies to market, such as CCUS, new hydrogen-based industrial plants, end of sales of new internal combustion engine cars by 2035 and boost electrification underpin the massive reduction in transport emissions. In 2050, cars on the road worldwide run-on electricity or fuel cells. Low-emissions fuels are essential where energy needs cannot easily or economically be met by electricity.

Reaching net zero by 2050 will require new technologies that are not available on the market yet. Major innovation efforts must occur over this decade in order to bring these new technologies to right time. Most of the global reductions in emissions in 2030 will come from technologies available today, but in 2050 almost half the reductions will come from technologies that are currently under development specially in the field of storage, batteries, hydrogen electrolysers, and direct air capture and storage

Set clear and key milestones to short, medium and long-term providing credible step-by-step plans to reach net zero target, will create confidence with all stakeholders describing ambition and fairness, with precise description of the targets, making a link to Paris Agreement goals, sharing the planning process and implementation plans.

FIGURE 40

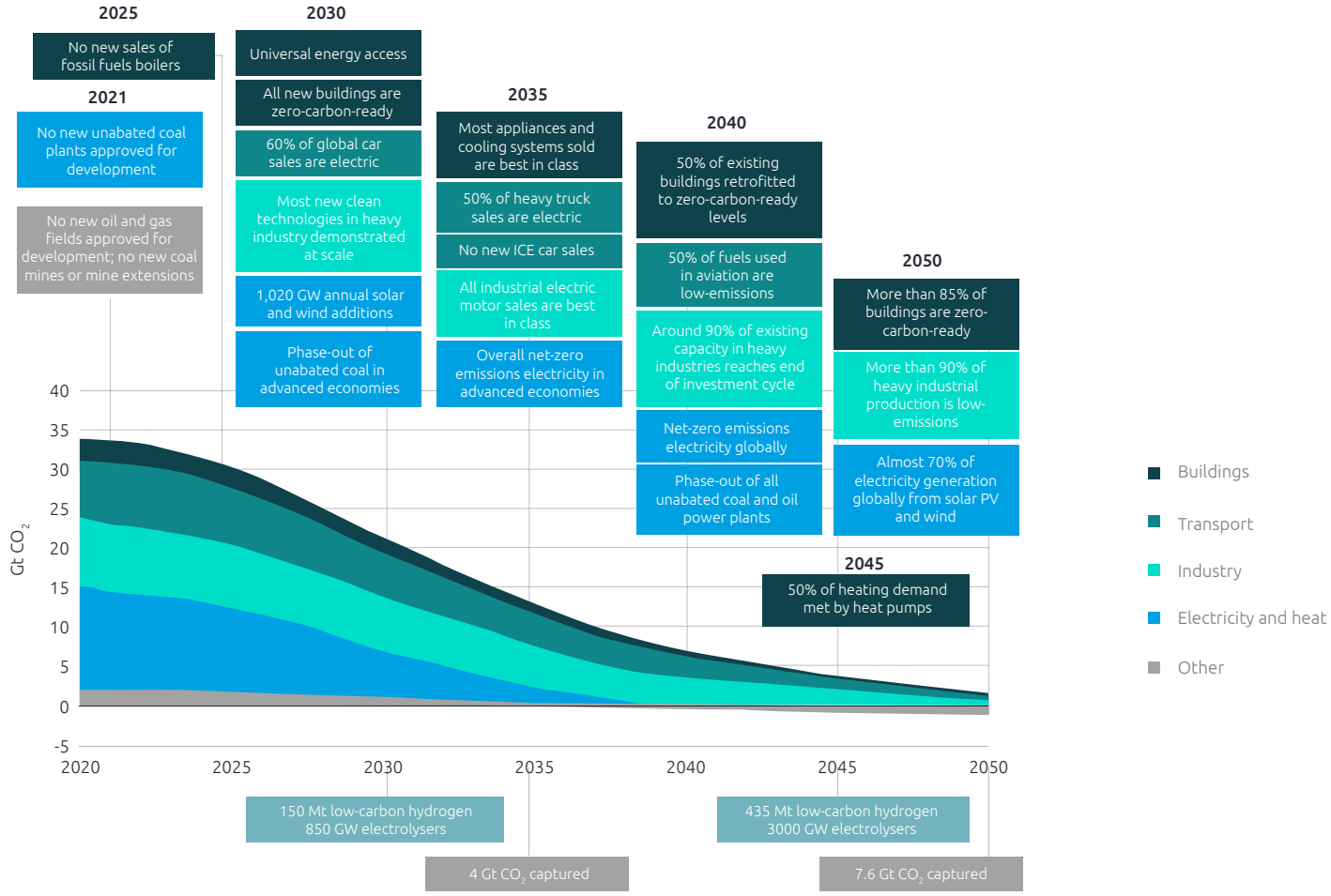
Annual CO_2 emissions savings in the net zero pathway, relative to 2020



Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

FIGURE 41

Key milestones in the pathway to net zero



Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

Governments, politicians, investors, business and industry players, and citizens must address these challenges everywhere.

Address emerging energy security risks from now will ensure reliable supplies of energy and critical related commodities at affordable prices rising in importance on the way to net zero, creating adequate terms for new investments required, digital enablers, grids, flexibility solutions, ….

Unprecedented international efforts and cooperation is pivotal for achieving net-zero emissions by 2050 worldwide. Net zero challenge is huge and global, the cooperation between countries will provide comfort scenarios to all stakeholders. Including comprehensive policy decisions and fiscal and tax regimes where in the net zero tax revenues from oil and gas sales will decline close to zero in long-term. Developed countries need to ramp up climate finance contributions to support developing countries.

FIGURE 42

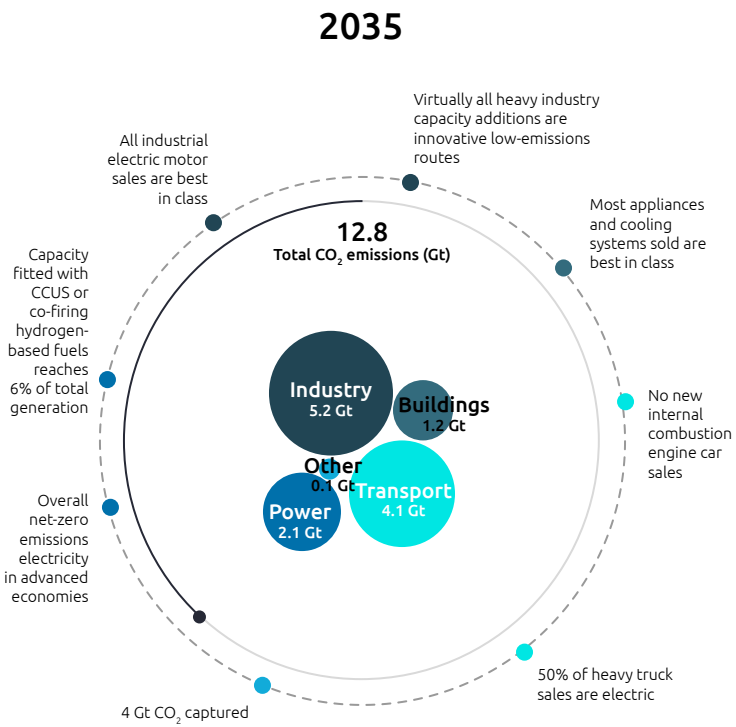


FIGURE 43

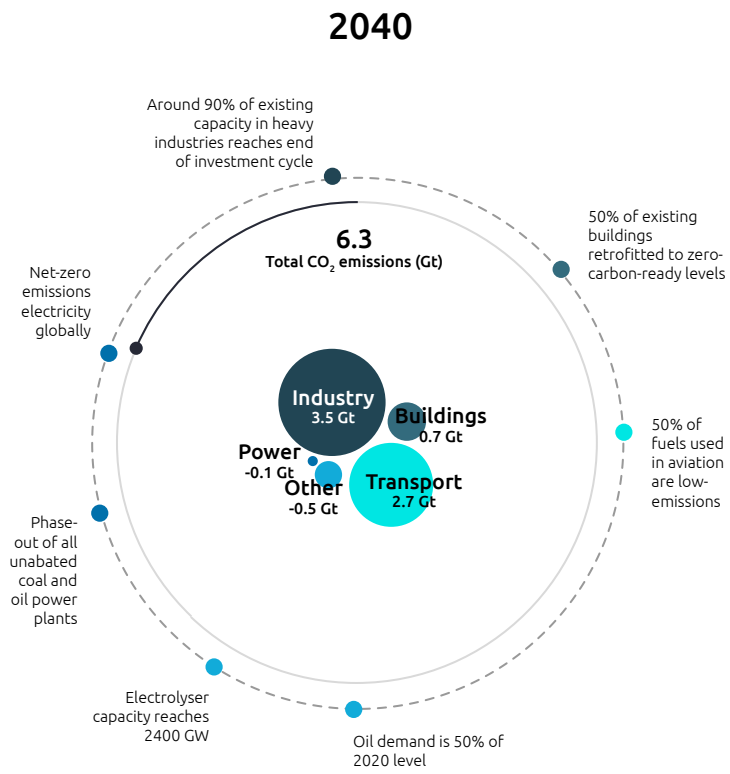
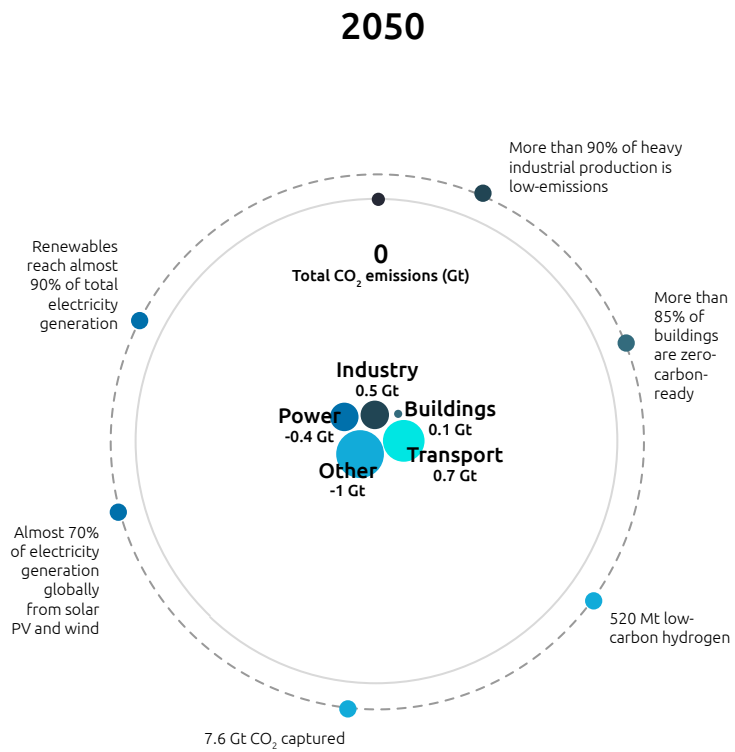


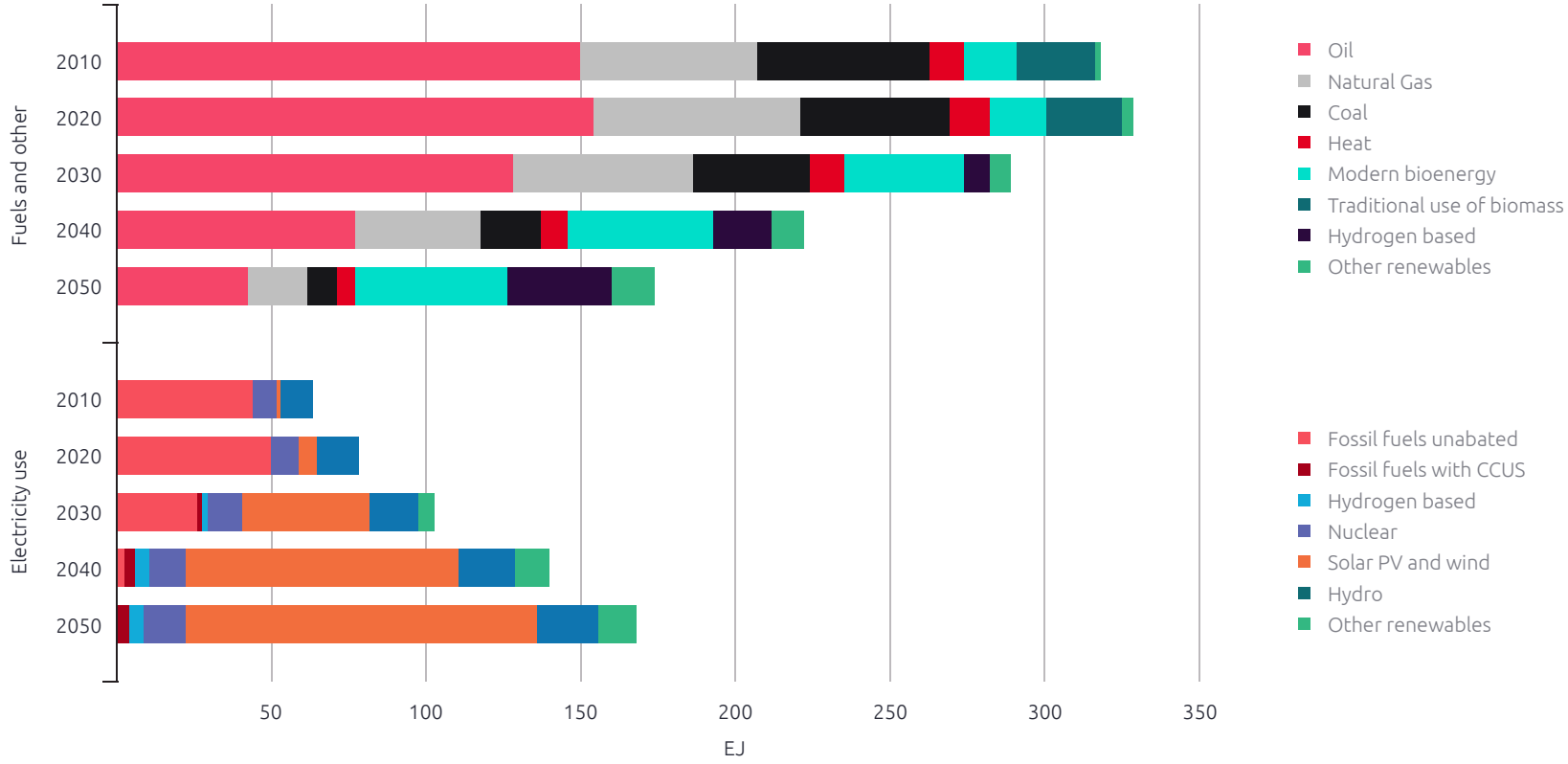
FIGURE 44



Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

FIGURE 45

Global total final consumption by fuel in the NZE



The share of electricity in final energy use jumps from 20% in 2020 to 50% in 2050
Note: Hydrogen-based includes hydrogen, ammonia and synthetic fuels.

Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

FIGURE 46

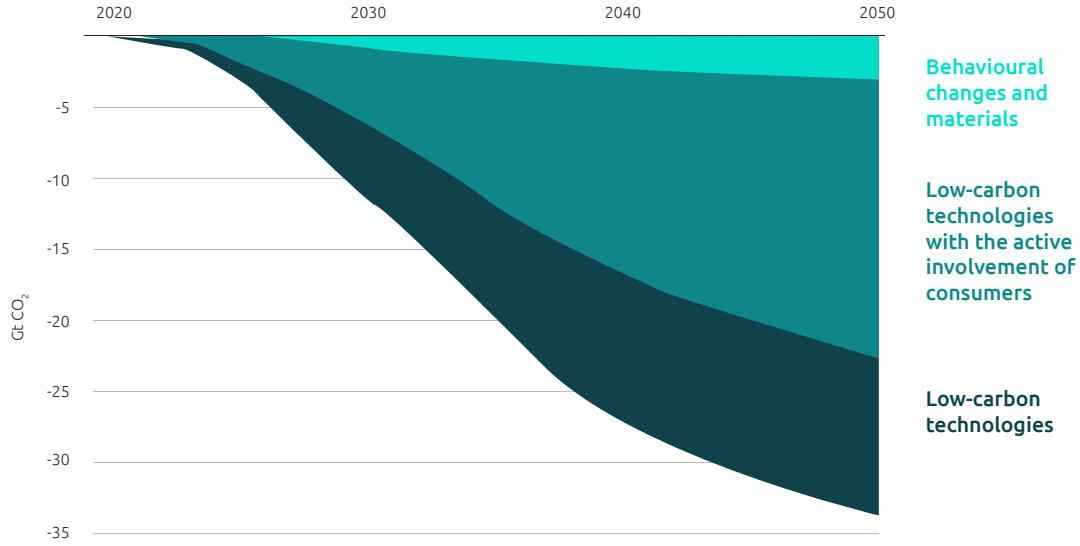
Emissions reductions by mitigation measures in the NZE 2020-2050

Solar, wind and energy efficiency deliver around half of emissions reductions to 2030 in the NZE, while electrification, CCUS and hydrogen ramp up thereafter.

Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

FIGURE 47

Role of technology and behavioural change in emissions reductions in the NZE



Source: IEA Net Zero by 2050 A Roadmap for the Global Energy Sector

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