INFORMATION NOTE

LATEST SCIENTIFIC CONSENSUS ON CLIMATE CHANGE

SYNTHESIS OF THE 3 WORKING GROUPS' CONTRIBUTIONS TO THE AR6 (SIXTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE)

ABOUT THE IPCC

The Intergovernmental Panel on Climate Change (IPCC) was created in 1988 by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO).

Its mandate is "to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options".[1]

It is made up of three working groups:

1. WGI focuses on the physical science basis
2. WGII deals with impacts, adaptation and vulnerability
3. WGIII focuses on climate change mitigation[2]

The IPCC conducts regular assessments of the existing scientific knowledge on climate change, in periodic cycles, and is organised in different expert groups. Right now the IPCC is conducting its 6th Assessment cycle. Each of the three working groups has already published a report in the last few months and, in late 2022, a so-called 'Synthesis Report' will be published (which will provide a synthesis of the three working group contributions).

The document you are reading now contains a summary of the reports of each of these three working groups, to facilitate comprehension and provide a solid background for future joint work.

1. https://www.ipcc.ch/
2. "Climate Change Mitigation refers to efforts to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior." https://www.unep.org/explore-topics/climate-action/what-we-do/mitigation#:~:text=Climate%20Change%20Mitigation%20refers%20to,management%20practices%20or%20consumer%20behavior.

WORKING GROUP I CONTRIBUTION PHYSICAL SCIENCE BASIS OF CLIMATE CHANGE

The Working Group (WG) I contribution provides a "summary of the understanding of the current state of the climate including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change." (p. 5)

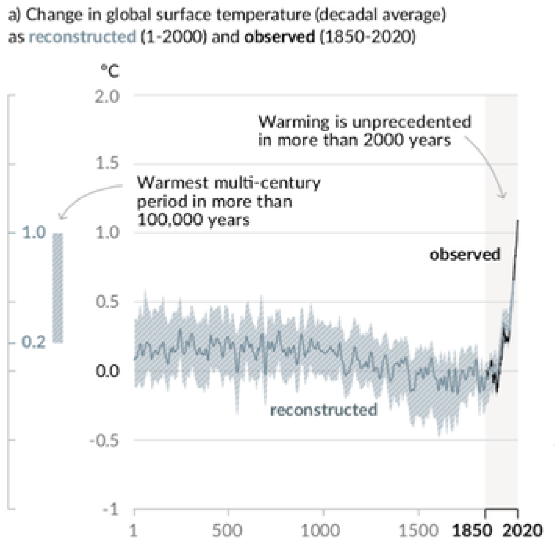
There is certainty that human activities have led to an increase in Greenhouse Gas concentrations present in the atmosphere since approximately the year 1750. In 2019, the annual average concentrations were: 410 ppm (parts per million) of carbon dioxide (CO2), 1866 ppb (parts per billion) of methane (CH4) and 332 ppb of nitrous oxide (N2O). CO2 concentrations have not been this high at least in the last 2 million years, whereas CH4 and N2O concentrations have not been this high at least in the last 800,000 years.

The increases in CO2 and CH4 concentrations since 1750 exceed by far the natural variations that have occurred between glacial and interglacial periods at least in the last 800,000 years, and that take thousands of years to develop. The increases in N2O concentrations since 1750 are similar to those registered in transitions between glacial and interglacial periods.

The global surface temperature[3] has been rising successively in the last four decades: each decade has been warmer than the previous one, and warmer than any decade since 1850. **Since 1970, the temperature has risen faster than in any other 50-year period in the last 2000 years**, at least.

It is estimated that human activities have led to an increase in global surface temperature of 1.07°C from 1850-1900 to 2010-2019. This warming rate is unprecedented in at least the last 2000 years.

3. "The term 'global surface temperature' is used in reference to both global mean surface temperature and global surface air temperature throughout this SPM." (WG I Summary for Policymakers page 6)



It is likely that human activity has contributed to an increase in global average precipitation over land since 1950.

Glaciers have been retreating since the 1990s, and the area of the Arctic Sea has decreased between 1979-1988 and 2019-2020. It is very likely that human influence has been the main driver.[4] Between 2011 and 2020, the annual average area of the Arctic Sea ice reached its lowest level at least since 1850. Snow cover in the Northern hemisphere has decreased since 1950, and the surface of the Greenland Ice Sheet has been melting in the last two decades. It is very likely that human influence has contributed.
"The rate of ice sheet loss increased by a factor of four between 1992–1999 and 2010–2019." (p. 15).

The global upper ocean (0-700 m) has been getting warmer since the 1970s due to human influence. The surface of the ocean has become more acidified because of human-caused CO2 emissions.

Global mean sea level has risen by 0.20 m between 1901 and 2018, very likely because of human activity, at least since 1971. Since 1900, the rise in sea level has been faster than in any century in the last 3000 years at least. The sea level rise has been caused by a warming climate, that in turn is leading to the melting of ice on land as well as thermal expansion from the warming of the ocean. "Together, ice sheet and glacier mass loss were the dominant contributors to global mean sea level rise during 2006-2018." (p. 15)

4. For Working Group I, the term 'main driver' means responsible for more than 50% of the change.

Since the previous IPCC report (AR5, published in 2014), there is stronger evidence that human-caused climate change is affecting weather and climate extremes all across the world.

- Hot extremes (including heatwaves) have grown in frequency and intensity in most land regions since the 1950s, while cold extremes (including cold waves) are less frequent and intense.
- Heavy precipitation events have grown in frequency and intensity in most land regions (where there is sufficient data) since the 1950s. Heavy precipitation associated with tropical cyclones have been increasing due to human-caused climate change.
- Human-caused climate change has contributed to a rise in droughts in some areas.
- Extreme events are increasingly occurring in a compound manner due to human-caused climate change since the 1950s, like concurrent heatwaves and droughts.

POSSIBLE CLIMATE FUTURES

This report evaluates how the climate might respond to five illustrative scenarios, referred to as Shared Socio-economic Pathways (SSP). The difference between the five scenarios is the amount of GHG emissions released into the atmosphere, which go from "very low" to "very high". Each SSP is given a number, which represents the approximate level of radiative forcing[5], and subsequent global warming, that would result from the scenario by 2100.

"Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades." (p. 17).

Projected effects of continued global warming:

- Land surface temperature will continue to rise more than ocean surface temperature.
- The Arctic will keep warming more than global surface temperature, more than two times the global warming rate.
- As global warming continues, it will intensify and increase the frequency of weather and climate extremes, like hot extremes (including heatwaves), heavy precipitation, droughts in some parts of the world, floods, and other rarer events. Tropical cyclones will become more frequent and wind speeds will increase.
- The permafrost will continue to thaw at an amplified rate. Seasonal snow cover, land ice and Arctic Sea ice will continue to decrease. It is likely that the Arctic will have almost no sea ice during September[6], at least once before 2050. In higher warming levels, this will happen more frequently.
- In scenarios with higher emissions, the land and the ocean ("carbon sinks")[7] become less effective at absorbing CO2.
- Greenhouse Gases that have already been emitted have led to, and/ or triggered changes that are irreversible for hundreds to thousands of years, including:
  - The continued rise in the warming, acidification and loss of oxygen of the ocean.

5.Radiative forcing is a key concept behind global warming and the greenhouse effect. Basically, radiative forcing is the difference between the energy that enters the Earth's atmosphere and the energy that leaves it. The Earth receives energy from the sun, in the form of solar radiation. Part of it is absorbed by the ocean and the atmosphere and part is reflected back to space as infrared radiation. Different factors influence how much energy is absorbed or reflected back to space. Among those factors are the greenhouse gases that human society has been emitting at increasing rates since the Industrial Revolution. These gases capture energy and alter the balance between the energy that enters the Earth's atmosphere and the energy that leaves it. When the amount of energy that enters the Earth's atmosphere is higher than the energy that leaves it, warming occurs. A simple example would be: if you turn on the heating in a room and close the windows, there is energy flowing in and less energy leaving. Therefore, the room will warm up. This is what's happening to our Earth right now. For more information: https://climate.mit.edu/explainers/radiative-forcing#:~:text=Radiative%20forcing%20is%20what%20happens,infrared%20radiation%20exiting%20as%20heat.

6. "monthly average sea ice area of less than 1 million km2 which is about 15% of the average September sea ice area observed in 1979-1988" (p. 21)

7. "Carbon reservoirs and conditions that take-in and store more carbon (i.e., carbon sequestration) than they release. Carbon sinks can serve to partially offset greenhouse gas emissions. Forests and oceans are large carbon sinks.", UNFCCC Glossary.

- The melting of mountain and polar glaciers will continue for decades or centuries. When thawed, permafrost releases carbon dioxide and it will continue to do so for hundreds of years.
- The rise of the mean ocean sea level will continue in the 21st century. The report mentions projected levels of sea rise that go from 0.28 m in very low emissions scenarios to 1.01 m in very high emissions scenarios by 2100, relative to 1995-2014. And projections go from 0.37 m to 1.88 m by 2150.
- The sea level is projected to keep rising for hundreds to thousands of years, and will stay at a higher level for thousands of years.

- High impact outcomes, which were previously deemed quite unlikely to occur, cannot be ruled out. These include the collapse of ice sheets, abrupt changes in ocean circulation, compound extreme weather events, forest dieback, melting of the Antarctic ice, and higher global warming levels than projected.

LIMITING GLOBAL WARMING

IPCC's Assessment Report N° 6, relative to AR5, has improved the estimation of the remaining carbon budgets.[8]

To limit human-caused global warming to a certain level, it is necessary to:

- limit CO_2 emissions, because "there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause" (p. 37), reaching net zero[9] CO_2 emissions at least;
- strongly reducing other greenhouse gas emissions.

Anthropogenic CO_2 removal (CDR) has the capacity to remove CO_2 from the atmosphere, storing it in reservoirs.

8. "The term carbon budget refers to the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a given probability, taking into account the effect of other anthropogenic climate forcers. This is referred to as the total carbon budget when expressed starting from the pre-industrial period, and as the remaining carbon budget when expressed from a recent specified date (see Glossary). Historical cumulative CO_2 emissions determine to a large degree warming to date, while future emissions cause future additional warming. The remaining carbon budget indicates how much CO_2 could still be emitted while keeping warming below a specific temperature level." (p. 37).
9. "condition in which anthropogenic carbon dioxide (CO_2) emissions are balanced by anthropogenic CO_2 removals over a specified period." (p. 37).

WORKING GROUP II CONTRIBUTION
IMPACTS, ADAPTATION AND VULNERABILITY

The introduction of the document includes a number of definitions:

Risk: "...the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems." (p. 7).

Hazard: "...the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources." (p. 7).

Exposure: "...the presence of people; livelihoods; species or ecosystems; environmental functions, services and resources; infrastructure; or economic, social or cultural assets in places and settings that could be adversely affected." (p. 7)

Vulnerability: "...the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." (p. 7).

Adaptation: "Adaptation is defined, in human systems, as the process of adjustment to actual or expected climate and its effects in order to moderate harm or take advantage of beneficial opportunities. In natural systems, adaptation is the process of adjustment to actual climate and its effects; human intervention may facilitate this." (p. 7).
"Adaptation is subject to hard and soft limits... Adaptation limits: The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions. Hard adaptation limit—No adaptive actions are possible to avoid intolerable risks. Soft adaptation limit—Options may exist but are currently not available to avoid intolerable risks through adaptive action." (p. 9).

Resilience: "...the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation." (p. 9)

"In the context of climate change, risk can arise from the dynamic interactions among climate-related hazards, the exposure and vulnerability of affected human and ecological systems. The risk that can be introduced by human responses to climate change is a new aspect considered in the risk concept." (p. 7).

The report presents 127 key risks.[10]

Adaptation helps to reduce exposure and vulnerability to climate change. Ecological systems adapt through ecological and evolutionary mechanisms, while human systems can either anticipate, react, increment or transform. Transforming implies changing "the fundamental attributes of a social-ecological system in anticipation of climate change and its impacts." (p. 9).

The report focuses on adaptation solutions that are effective, feasible and respectful of justice principles. In this report, **climate justice** is meant to include distributive justice,[11] procedural justice[12] and recognition.[13] There is a focus on "**transformation and system transitions in energy**; land, ocean, coastal and freshwater ecosystems; urban, rural and infrastructure; and industry and society" (p. 9).

CLIMATE CHANGE IMPACTS

- More frequent and intense **weather extremes** have caused "widespread, pervasive" (p. 11) impacts "to ecosystems, people, settlements, and infrastructure" (p. 9), including "increased heat-related human mortality", "warm-water coral bleaching and mortality", "increased drought related tree mortality", and more areas burned due to wildfires in some regions.

10. "Key risks have potentially severe adverse consequences for humans and social-ecological systems resulting from the interaction of climate related hazards with vulnerabilities of societies and systems exposed." (p. 7)
11. Distributive justice: the distribution of benefits and burdens among individuals, nations, regions and generations of human beings.
12. Procedural justice refers to the fairness of decision-making processes, including who decides and who participates in decision making.
13. Recognition is defined as "basic respect and robust engagement with and fair consideration of diverse cultures and perspectives." (p. 9)

- Damages and losses to ecosystems, including terrestrial, freshwater, coastal, and open marine ecosystems. Climate change impacts are more widespread than previously assessed, and have negative socioeconomic effects. Species are being affected either because they are having to shift in direction to the poles or to higher altitudes in response to the warming temperatures, or they are suffering due to ice loss, and/ or extreme weather events.
- Climate change negatively affects water and food security, by impacting agricultural productivity, and by leading to the warming and acidification of the ocean. Food and water insecurity are most suffered in several locations of Africa, Asia, Central and South America, Small Islands and the Arctic. Grassroot communities are increasingly experiencing malnutrition, especially Indigenous communities, small scale food producers and low-income populations, partly as a consequence of decreased food production and access to food.
- Negative impacts on health, including mental health. Causes: hot extremes; food, water and vector-borne diseases, animal and human diseases related to climate change. Mental health issues as a consequence of weather extremes.
- Negative impacts on infrastructure in urban settings. “Observed impacts are concentrated amongst the economically and socially marginalised urban residents, e.g., in informal settlements”. “Infrastructure, including transportation, water, sanitation and energy systems have been compromised by extreme and slow-onset events, with resulting economic losses, disruptions of services and impacts to well-being” (p. 13).
- Negative economic impacts to sectors that are exposed to climate, like agriculture, forestry, fishery, energy and tourism. Some regions have experienced positive economic impacts, for example due to reduced energy consumption, and/ or shifts in agriculture and tourism.
- Climate hazards in combination with high vulnerability contribute to humanitarian crises. Climate and weather extremes are causing displacement - Small Island States are “disproportionately affected” (p. 13). Critical food insecurity and malnutrition related to floods and droughts have become more frequent in Africa and Central and South America.

VULNERABILITY

The vulnerability to climate change of ecosystems and human beings varies according to regions, “driven by patterns of intersecting socioeconomic development, unsustainable ocean and land use, inequity, marginalization, historical and ongoing patterns of inequity such as colonialism, and governance… Approximately **3.3 to 3.6 billion people live in contexts that are highly vulnerable to climate change** (high confidence). A high proportion of species is vulnerable to climate change (high confidence). **Human and ecosystem vulnerability are interdependent** (high confidence). Current unsustainable development patterns are increasing exposure of ecosystems and people to climate hazards (high confidence).” (p. 14).

There is growing evidence that when human beings destroy ecosystems, they increase their own vulnerability to climate change. “**Unsustainable land-use and land cover change, unsustainable use of natural resources, deforestation, loss of biodiversity, pollution, and their interactions adversely affect the capacities of ecosystems, societies, communities and individuals to adapt to climate change** (high confidence). Loss of ecosystems and their services has cascading and long-term impacts on people globally, especially for Indigenous Peoples and local communities who are directly dependent on ecosystems, to meet basic needs (high confidence)” (p. 14).

There are human-induced factors that go beyond climate change that increase the vulnerability of ecosystems to climate change, including the “unsustainable use of natural resources, habitat fragmentation, and ecosystem damage by pollutants” (p. 14).

WORKING GROUP III CONTRIBUTION
MITIGATION OF CLIMATE CHANGE

The Working Group III (WG III) contribution to the IPCC's Sixth Assessment Report (AR6) focuses on mitigation of climate change. It is based on previous IPCC reports as well as other UN assessments, and presents new findings in relevant literature.

TRENDS

- *"Evolving international landscape"*

According to the literature reviewed by WG III, there is an evolving international landscape, including changes in the United Nations Framework Convention on Climate Change (UNFCCC) process, like the Kyoto Protocol outcomes and the adoption of the Paris Agreement. Furthermore, the UN General Assembly adopted the Agenda 2030 for Sustainable Development in 2015. Lastly, the role played by international cooperation, finance and innovation is also evolving.

- *"Increasing diversity of actors and approaches to mitigation"*

The literature indicates that **non governmental** and **sub-national actors** are playing increasingly important roles in the fight against climate change. These include cities, businesses, Indigenous Peoples, citizens (represented, e.g., by local communities and youth), international initiatives and public-private initiatives.

- *"Close linkages between climate change mitigation, adaptation and development pathways"*

Countries' economic development influences their GHG emissions, as well as the related mitigation challenges and opportunities. Climate mitigation is more "acceptable, durable and effective" when designed and implemented along with a sustainable development, equity and poverty eradication approach.

CONTINUED RISE IN EMISSIONS

As stated by the Working Group I report, total net anthropogenic GHG emissions[14] have continued to rise during the period 2010-2019. In 2019, GHG emissions were about 12% higher than in 2010 and 54% higher than in 1990. The different groups of greenhouse gases have all been increasing, but at different rates. CO2 from fossil fuels and industry is the GHG that grew the most in absolute terms by 2019, followed by methane. Fluorinated gases had the highest growth in relative terms (levels were low in 1990). Net anthropogenic CO2 emissions from land use, land-use change and forestry vary greatly each year and "are subject to large uncertainties" (p. 4).

During the decade 2010-2019 average annual GHG emissions were higher than in any previous decade. However, the emissions' growth rate was lower than in the 2000-2009 decade.

There has been a rise in **average global per capita net anthropogenic GHG emissions from 1990 to 2019** - from 7.7 to 7.8 tCO2-eq. (CO2 equivalent Tons).

Since 2010, net anthropogenic GHG emissions have risen across all major sectors. **Urban areas** release a growing share of emissions. GDP energy intensity and energy carbon intensity have led to CO2 emissions reductions from fossil fuels and industrial processes. But these reductions have been lower than emissions' increases from "rising global activity levels in industry, energy supply, transport, agriculture and buildings."

HISTORICAL GROWTH OF CO2 EMISSIONS

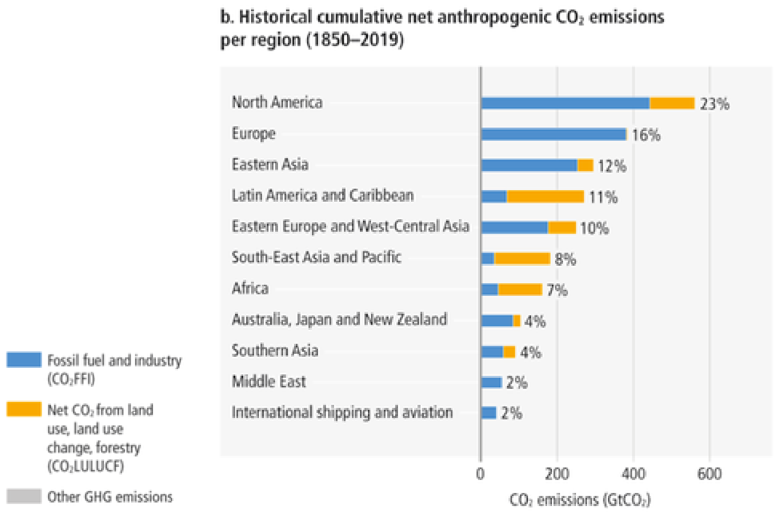
- The historical cumulative net CO2 emissions between 1850 and 2019 is 2400 +/- 240 Gt CO2 (Gigatons of CO2).
  - 58% were released between 1850 and 1989 [1400 +/- 195 GtCO2] [140 years]
  - about 42% were released **between 1990** and **2019** [1000 +/- 90 GtCO2] [30 years]

⇒ About 17% of historical cumulative net CO2 emissions since 1850 occurred between 2010 and 2019 [410 +/- 30 GtCO2].

14. NET GHG EMISSIONS: "releases of greenhouse gases from anthropogenic sources minus removals by anthropogenic sinks..." (p. 4)
"Global net anthropogenic GHG emissions include CO2 from fossil fuel combustion and industrial processes (CO2- FFI); net CO2 from land use, land use change and forestry (CO2-LULUCF) [FOOTNOTE 9]; methane (CH4); nitrous oxide (N2O); fluorinated gases (HFCs; PFCs, SF6, NF3)."

WIDE VARIATIONS IN HISTORICAL CONTRIBUTIONS TO CUMULATIVE NET ANTHROPOGENIC CO2 EMISSIONS (1850-2019)

- Historical contributions vary across regions:
  - In terms of total magnitude
  - In terms of contributions to CO2 from fossil fuels and industry (CO2-FFI) (1650 +/- 73 GtCO2-eq)
    - Least Developed Countries (LDCs) contributed <0.4% of historical cumulative CO2-FFI emissions (1850-2019)
    - Small Island Developing States (SIDS) contributed 0.5%.
  - In terms of contributions to net CO2-LULUCF (760 +/- 220 GtCO2-eq) emissions.



In 2019:

- 48% of the global population lived in countries emitting on average > 6t CO2-eq per capita, excluding CO2-LULUCF.
- 35% lived in countries emitting > 9 tCO2-eq per capita.
- 41% lived in countries emitting < 3 tCO2-eq per capita.

“A substantial share of the population in these low emitting countries lack access to modern energy services. Eradicating extreme poverty, energy poverty, and providing decent living standards to all in these regions in the context of achieving sustainable development objectives, in the near-term, can be achieved without significant global emissions growth.” (p. 9)

CARBON BUDGET[15]

- Current estimates:
  - **To limit global warming to 1.5 °C (with a 50% probability)**, the remaining carbon budget from 2020 onwards is 500 Gt CO2. This represents:
    - about 50% of what was emitted between 1990 and 2019.
    - Only about 1 / 4 more than the cumulative net CO2 emitted between 2010 and 2019.
  - To limit global warming to 2°C (with a 67% probability), the remaining carbon budget is 1150 Gt CO2.
    - About 3 times the estimated emissions between 2010 and 2019.
- "Remaining carbon budgets depend on the amount of non-CO2 mitigation (±220 Gt CO2) and are further subject to geophysical uncertainties."
- If we look at the total carbon budget to limit global warming to 1.5 °C (with a 50% probability), 4 / 5 of emissions were emitted between 1850 and 2019 (about 2900 GtCO2). This means that "historical emissions between 1850 and 2019 constitute a large share of total carbon budgets for these global warming levels" (p. 4).

WHERE DID EMISSIONS COME FROM IN 2019?

- **34% energy supply sector** [20 GtCO2-eq]
- **24% industry** [14 GtCO2-eq]
- **22% agriculture, forestry and other land use** (AFOLU) [13 GtCO2-eq]
- 15% transport [8.7 GtCO2-eq]
- 6% buildings [3.3 GtCO2-eq]

"If emissions from electricity and heat production are attributed to the sectors that use the final energy, 90% of these indirect emissions are allocated to the industry and buildings sectors, increasing their relative GHG emissions shares from 24% to 34%, and from 6% to 16%, respectively. After reallocating emissions from electricity and heat production, the energy supply sector accounts for 12% of global net anthropogenic GHG emissions." (p 7).

15. "The carbon budget is the maximum amount of cumulative net global anthropogenic CO2 emissions that would result in limiting global warming to a given level, with a given likelihood... The total carbon budgets reported here are the sum of historical emissions from 1850 to 2019 and the remaining carbon budgets from 2020 onwards, which extend until global net zero CO2 emissions are reached" (p. 5)

URBAN AREAS - INCREASING SHARE OF EMISSIONS

- "The global share of emissions that can be attributed to urban areas is increasing.
- In 2015, urban emissions were estimated to be 25 GtCO2-eq (about 62% of the global share) and
- in 2020, 29 GtCO2- eq (67-72% of the global share).
- The drivers of urban GHG emission are complex and include population size, income, state of urbanisation and urban form." (p. 8).
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- "This estimate is based on consumption-based accounting, including both direct emissions from within urban areas, and indirect emissions from outside urban areas related to the production of electricity, goods and services consumed in cities. These estimates include all CO2 and CH4 emission categories except for aviation and marine bunker fuels, land-use change, forestry and agriculture." (p. 8).
- Consumption-based emissions are a consequence of the production of goods and services consumed by an entity (a person, company, country or region).

WIDE VARIATIONS REGARDING WHERE EMISSIONS COME FROM

(excluding CO2-LULUCF)

- There are regional and national differences (which partly reflect different development stages).
- Per capita emissions vary according to income levels
  - **The 10% of households with the highest per capita emissions contribute a disproportionately large share of global household GHG emissions: 34-45% of global consumption-based household GHG emissions.**
  - The middle 40% contribute 40-53%,
  - The bottom 50% contribute 13-15%.
  - Least Developed Countries (LDCs)[16]
    - Emitted an estimate of 3.3% of global GHG emissions (2019)
    - 1.7 tCO2-eq per capita.
  - Small Island Developing States (SIDS)[17]
    - Emitted an estimate of 0.60% of global GHG emissions (2019)
    - 4.6 tCO2-eq per capita

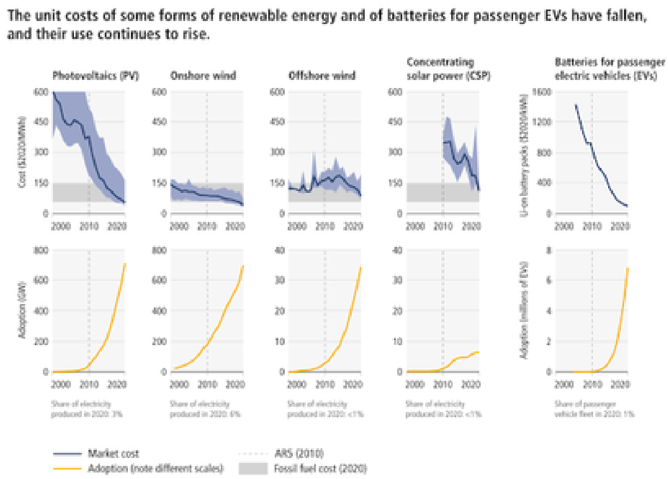
16. Country grouping that cuts across geographic regions
17. Country grouping that cuts across geographic regions

CHANGE IS POSSIBLE!

"At least 18 countries have sustained production-based GHG and consumption-based CO2 emission reductions for longer than 10 years. Reductions were linked to energy supply decarbonisation, energy efficiency gains, and energy demand reduction, which resulted from both policies and changes in economic structure. Some countries have reduced production-based GHG emissions by a third or more since peaking, and some have achieved several years of consecutive reduction rates of around 4 %/yr, comparable to global reductions in scenarios limiting warming to 2°C (>67%) or lower. These reductions have only partly offset global emissions growth." (p 10).

REDUCED UNIT COSTS AND INCREASED DEPLOYMENT OF LOW-EMISSION TECHNOLOGIES

- Sustained decreases in the unit costs of solar energy (85%), wind energy (55%), and lithium-ion batteries (85%) (since 2010).
- Large increases in their deployment, varying widely across regions.



WHAT POLICIES HAVE BEEN INSTRUMENTAL TO ACHIEVE THIS?

- The decreased costs of low-emission technologies and their increased adoption have been made possible by a combination of policy instruments, including:
- Public Research and Development (R&D), meaning that the public sector directly or indirectly engaged in research activities, to obtain knowledge to be later applied to development activities, like the production of prototypes, processes, materials, etc.

- Funding for demonstration and pilot projects, meaning that governments funded projects aimed at testing and/ or demonstrating materials, processes or technologies.
- Demand pull instruments, like subsidies to achieve scale. Demand pull instruments are aimed at influencing the market and increasing demand for certain products or technologies. For example, governments can provide subsidies for solar panels, which make it more likely that citizens will want, and be able to, buy solar panels.

According to the report, the most effective policy packages have been those designed and adapted to national contexts and technological characteristics.

WHAT ABOUT DISTRIBUTIONAL, ENVIRONMENTAL AND SOCIAL IMPACTS?

- **"Appropriately designed policies and governance have helped address distributional impacts and rebound effects." (p. 12).**
- **"Innovation has provided opportunities to lower emissions and reduce emission growth and created social and environmental co-benefits." (p. 12).**
- **"Both tailored policies and comprehensive policies addressing innovation systems have helped overcome the distributional, environmental and social impacts potentially associated with global diffusion of low-emission technologies." (p. 12).**

WHAT ABOUT DEVELOPING COUNTRIES?

- **"Innovation has lagged in developing countries due to weaker enabling conditions."** (p 12).
- "Adoption of low-emission technologies lags in most developing countries, particularly least developed ones, due in part to weaker enabling conditions, including limited finance, technology development and transfer, and capacity. In many countries, especially those with limited institutional capacities, several adverse side-effects have been observed as a result of diffusion of low-emission technology, e.g., low-value employment, and dependency on foreign knowledge and suppliers. **Low-emission innovation along with strengthened enabling conditions can reinforce development benefits**, which can, in turn, create feedbacks towards greater public support for policy." (p 12 & 13).

DIGITALISATION: YES, BUT...

- "Digital technologies can contribute to climate change mitigation and the achievement of several SDGs. For example, sensors, Internet of Things,[18] robotics, and artificial intelligence can improve energy management in all sectors, increase energy efficiency, and promote the adoption of many low-emission technologies, including decentralised renewable energy, while creating economic opportunities" (p 13).
- "However, some of these climate change mitigation gains can be reduced or counteracted by growth in demand for goods and services due to the use of digital devices. Digitalisation can involve trade-offs across several SDGs, e.g., increasing electronic waste, negative impacts on labour markets, and exacerbating the existing digital divide." (p 13)
- IN SUM, **"Digital technology supports decarbonisation only if appropriately governed."** (p 13).

MITIGATION POLICIES SINCE AR5

"There has been a **consistent expansion of policies and laws addressing mitigation** since AR5 at the national and sub-national levels. This has led to the avoidance of emissions that would otherwise have occurred and increased investment in low-GHG technologies and infrastructure. Policy coverage of emissions is uneven across sectors." (p 14)

By 2020,

- + 20% of global GHG emissions were covered by carbon taxes or emissions trading systems, although coverage and prices have been insufficient to achieve deep reductions
- There were 'direct' **climate laws** focused primarily on GHG reductions in 56 countries covering 53% of global emissions.

"Policy coverage remains limited for emissions from agriculture and the production of industrial materials and feedstocks" (p. 14, 15).

"In many countries, policies have enhanced energy efficiency, reduced rates of deforestation and accelerated technology deployment, leading to avoided and in some cases reduced or removed emissions." (p. 15).

18. For further information about the Internet of Things, please refer to https://digital-strategy.ec.europa.eu/en/policies/internet-things-policy or this article published by Forbes https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/

FINANCE AND CLIMATE ACTION

“Progress on the alignment of financial flows towards the goals of the Paris Agreement remains slow and tracked climate finance flows are distributed unevenly across regions and sectors.” (p 14).

“Annual tracked total financial flows for climate mitigation and adaptation increased by up to 60% between 2013/14 and 2019/20 (in USD2015), but average growth has slowed since 2018. These financial flows remained heavily focused on mitigation, are uneven, and have developed heterogeneously across regions and sectors.” (p. 15).

“In 2018, public and publicly mobilised private climate finance flows from developed to developing countries were below the collective goal under the UNFCCC and Paris Agreement to mobilize USD 100 billion per year by 2020 in the context of meaningful mitigation action and transparency on implementation.” (p. 15). This finance gap still persists today.

“Public and private finance flows for fossil fuels are still greater than those for climate adaptation and mitigation... Markets for green bonds, ESG (environmental, social and governance) and sustainable finance products have expanded significantly since AR5. Challenges remain, in particular around integrity[19] and additionality,[20] as well as the limited applicability of these markets to many developing countries.” (p. 15).

EFFECTS OF THE KYOTO PROTOCOL & THE PARIS AGREEMENT

“The Kyoto Protocol led to reduced emissions in some countries and was instrumental in building national and international capacity for GHG reporting, accounting and emissions markets... At least 18 countries that had Kyoto targets for the first commitment period have had sustained absolute emission reductions for at least a decade from 2005, of which two were countries with economies in transition.” (p. 14).

“The Paris Agreement, with nearly universal participation, has led to policy development and target-setting at national and sub-national levels, in particular in relation to mitigation, as well as enhanced transparency of climate action and support.” (p. 14).

19. The European Commission’s glossary of useful terms linked to markets in financial instruments defines market integrity as “the fair and safe operation of markets, without misleading information or inside trades, so that investors can have confidence and be sufficiently protected”. https://ec.europa.eu/info/sites/default/files/glossary_en_1.pdf

20. The IPCC has defined additionality as: “Reduction in emissions by sources or enhancement of removals by sinks that is additional to any that would occur in the absence of a Joint Implementation or a Clean Development Mechanism project activity as defined in the Kyoto Protocol Articles on Joint Implementation and the Clean Development Mechanism. This definition may be further broadened to include financial, investment, and technology additionality. Under financial additionality, the project activity funding shall be additional to existing Global Environmental Facility, other financial commitments of Parties included in Annex I, Official Development Assistance, and other systems of co-operation. Under investment additionality, the value of the Emissions Reduction Unit /Certified Emission Reduction Unit shall significantly improve the financial and/or commercial viability of the project activity. Under technology additionality, the technology used for the project activity shall be the best available for the circumstances of the host Party.” https://archive.ipcc.ch/ipccreports/tar/wg3/index.php?idp=454

PROJECTED GHG EMISSIONS AND ASSOCIATED GLOBAL WARMING

"Projected cumulative future CO2 emissions over the lifetime of existing and currently planned fossil fuel infrastructure without additional abatement[21] exceed the total cumulative net CO2 emissions in pathways that limit warming to 1.5° (>50%) with no or limited overshoot." (p. 19).

To limit global warming to 1.5°, global GHG emissions should peak at the latest before 2025 and global CO2 emissions should reach net zero in the early 2050s. By 2030 and 2040, there should be deep reductions in GHG emissions, especially reductions in methane emissions.[22] This would help reduce peak warming and "the likelihood of overshooting warming limits" (p 31). It would also "lead to less reliance on net negative CO2 emissions" and less carbon dioxide removal to reverse warming. The emissions released until net zero is reached will determine the level of peak warming.

If policies are not strengthened beyond what was implemented toward the end of the year 2020, GHG emissions are projected to continue rising after 2025, "leading to a median global warming of 3.2 by 2100." (p. 21).

Compared to the IPCC's 5th Assessment Report (2014), the likelihood of limiting warming to 1.5°C has declined, on average.

MITIGATION STRATEGIES

"All mitigation strategies face implementation challenges" (P. 33).

- Reducing GHG emissions in the energy sector would require:
  - Reducing overall fossil fuel use.
  - Minimising the use of unabated fossil fuels and using Carbon Dioxide Capture and Storage (CCS)[23] in the remaining fossil system.

21. Abatement: reducing the amount of GHG released from fossil fuel infrastructure.
22. "Due to the short lifetime of CH4 in the atmosphere, projected deep reduction of CH4 emissions up until the time of net zero CO2 in modelled mitigation pathways effectively reduces peak global warming" (p. 31).

23. There is a certain level of controversy regarding the use of Carbon Dioxide Carbon and Storage. Some Civil Society Organizations, like CIDSE, have expressed their opposition to this approach to emissions' reduction. They warn that its effectiveness has not yeen been proven, making them risky as a mitigation strategy. For this reason, they argue, the climate response should not rely on CCS. WWF also points towards the uncertainties regarding this technology, and its subsequent riskiness as a climate mitigation approach. WWF stresses that the priority should be to deeply and immediately cut GHG, yet it recognizes that CCS will likely also be necessary in order to limit the temperature rise to 1.5 °C.
See for example: https://www.cidse.org/2022/04/04/catholic-agencies-call-for-urgent-climate-mitigation-action-echoing-scientific-research/
https://www.arcticwwf.org/the-circle/stories/can-carbon-removal-save-us/

- Transitioning from fossil fuels (without CCS) to very low or zero-carbon energy sources - such as renewables or fossil fuels with CCS
  - To limit warming to 1.5°, the use of fossil fuels should decrease as follows:
    - Coal - should decline by a median value of 95% in 2050 compared to 2019
    - Oil - should decline by a median value of 60% in 2050 compared to 2019
    - Gas - should decline by a median value of 45% in 2050 compared to 2019
- Electrifying the energy system: To limit warming to 1.5°, by 2050, almost all electricity should come from zero or low-carbon sources, like renewables or fossil fuels with CCS. Also, energy demand should be increasingly supplied with electrified sources.
- Using sustainable biofuels or low-emissions hydrogen, when electrification is less practicable.
- Energy conservation and efficiency.
- Greater integration of the overall energy system (in terms of physical infrastructure, institutional and operational settings).
- National and regional circumstances will make energy strategies work more or less effectively.

- Reducing industry emissions would entail:
  - Adopting new production processes that use low and zero GHG electricity, hydrogen, fuels and carbon management.
  - Through coordinated action along value chains, to promote all mitigation options:
    - Demand management
    - Energy and materials efficiency
    - Circular material flows
    - Abatement technologies
    - Transformational changes in production processes
- For urban areas' emissions:
  - Infrastructure and urban form transformation, through low-emission development pathways towards net-zero emissions;
  - Reducing or changing energy and material consumption (i.e. the consumption of all types of products and materials);
  - Electrification;
  - Enhancing carbon uptake and storage in the urban environment;

- Reducing emissions both within and beyond cities' administrative boundaries, through supply chains. This way cities can have positive, cascading effects.
- For existing and new buildings:
  - Sufficiency measures[24]
  - Efficiency measures;
  - Renewable energy measures;
  - Removing barriers to decarbonisation, like stopping the expansion of gas networks and gas use in buildings.[25]
- For the transport sector:
  - To reduce transport sector emissions in developed countries;
  - To limit emissions' increase in developing countries, e.g. through enhancing public transport and promoting active mobility (walking and biking).
  - Electric vehicles powered by low emissions electricity:
    - Electric vehicles' prices are decreasing and their adoption is increasing.
    - They require continued investments to support infrastructure in order to increase deployment.
  - Promote the use of sustainable biofuels;
  - Changes in urban form (e.g. bringing residential and office buildings closer);
  - Programmes to encourage consumer behaviour change (e.g. through transport pricing);
  - Investing in public and active transport infrastructure (bike and pedestrian pathways);
  - Systemic changes like teleworking, digitalisation, supply change management, smart and shared mobility
  - Need for more CO2 emissions mitigation technologies for aviation and shipping.
- Agriculture, forestry and other land use (AFOLU) mitigation options can deliver large-scale GHG emissions reductions; however, there are barriers to implementation and trade-offs:
    - Like competing demands on land, conflicts with food security and livelihoods, cultural aspects, etc.
  - There are co-benefits that go hand in hand with GHG emissions reduction;
  - Conservation, improved management, and restoration of forests and other ecosystems offer sustainable opportunities;
  - Desirable demand side measures exist, like sustainable healthy diets.

24. Sufficiency measures or policies are those directed at avoiding or reducing consumption (of energy, materials, water, resources in general), yet still contributing to human wellbeing, respecting the planetary boundaries.
25. See https://climateactiontracker.org/documents/1018/CAT_2022-03-09_Report_DecarbonisingBuildings.pdf

- Demand side mitigation:
    - High socio-economic status individuals have the highest potential for reducing emissions;

Changes in infrastructure use Influence demand patterns and ways of providing services

- End-use technology adoption;
- **Socio-cultural and behavioural change should be promoted**;
- Choice "architecture"
    - To **encourage people to make low GHG emissions decisions, like diet choices, reducing food waste, adapting heating and cooling, etc.**
    - **Inequality and status consumption**[26] are important to address.

- Deploying carbon dioxide removal (CDR) methods[27]
    - To counterbalance hard-to-abate, residual GHG emissions
    - According to the WG III report, CDR is "unavoidable if net zero CO2 or GHG emissions are to be achieved" (p. 47)
    - How much CDR is needed and when will depend on the overall GHG emissions reductions.
    - There are feasibility and sustainability constraints.
    - CO2 can be removed from the atmosphere through different processes.

ECONOMIC FEASIBILITY (AND CONVENIENCE) OF MITIGATING CLIMATE CHANGE

- "The global economic benefit of limiting warming to 2 °C is reported to exceed the cost of mitigation in most of the assessed literature" (p. 48).
- The more stringent the climate mitigation, the more economic benefits there will be from avoiding climate change impacts and reducing adaptation costs.

26. Status consumption: consumption of goods and services which connote social prestige.
27. CDR is considered controversial by some CSOs. The information included in this document represents the view of the IPCC, not necessarily of ESC and its members.

FINAL COMMENTS

The information synthesised in this document seeks to provide a solid, scientific background for future advocacy and pedagogy work of JESC and its partners. Particularly, it aims at enabling us to better engage in the discussions leading up to the upcoming UNFCCC Climate Change Conference (COP27), which will take place in November, in Egypt. Beyond this specific advocacy opportunity, hopefully the information contained in this document will also empower us to be more effective and impactful when advocating for stronger, more ambitious European level climate action.

For more information, please refer to the IPCC website.