HSBC Global Research

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IPCC climate science

Mitigation options – the 10 points you need to know

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Climate Change - Global

- IPCC WG III report lead author says “It’s now or never”
- Mitigation options are widespread but sufficient deployment requires adequate finance & broad stakeholder involvement
- We think investors should look for the most cost-effective strategies to decarbonise their portfolios and the economy

Wai-Shin Chan, CFA
Head, Climate Change Centre; Head, ESG Research
The Hongkong and Shanghai Banking Corporation Limited

Polo Heung
Associate, ESG Research
The Hongkong and Shanghai Banking Corporation Limited

Amy Tyler
ESG Analyst
HSBC Bank plc

Extra time: The UN’s climate science body, the Intergovernmental Panel on Climate Change (IPCC), has released the third report of its sixth assessment cycle (AR6) on *Mitigation of Climate Change*. The report release was delayed due to controversies such as the pace of fossil fuel phase down.

A later draw: Emissions are still growing, although the pace is slowing a little and this pushes out the “dates for reaching net zero”. Without rapid decarbonisation, we are heading for 3.2°C of warming. Regional contributions vary and this highlights the inequality of development and the many social aspects of climate mitigation.

Substitutions: The IPCC laid out decarbonisation options and strategies across six key sectors including energy, transport and buildings. Some sectors can contribute more but this does not change the aggregate reduction required. Technology can be an enabler to reductions but this could be “counterbalanced by growth in demand”. Emissions of between 40% & 70% could be saved from “comprehensive demand-side strategies across all sectors”, especially by “individuals with high socio-economic status”.

Red card: Although there was discussion of carbon dioxide removal technologies, the emissions from current and planned fossil fuel infrastructure would exceed the carbon budget and breach temperature goals. The IPCC emphasized the long-term economic benefits of addressing climate change now, as well as accelerated financial support. We consider investors as integral to awareness, planning and engagement.

Figure 1: Ten key points from the IPCC’s WG III report on mitigation options

1. We are headed for 3.2°C of warming without immediate action
2. Emissions are growing; the rate of growth is slowing but is uneven across sectors
3. There are wide regional disparities in emissions contribution and consumption
4. The carbon budget is finite and is running out more quickly
5. Current fossil fuel use and infrastructure would exceed the carbon budget
6. Non-CO_2 emissions such as methane have a large part to play
7. All sectors must decarbonise but doing less in one means compensating in another
8. Mitigation options by sector vary with time, viability and cost
9. CDR is required and unavoidable but needs to be commercialized
10. Economic benefits outweigh the costs, financial support is essential

Source: HSBC (based on IPCC, AR6, WG III)

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The science of climate change according to the IPCC

Box 1: What is the IPCC?

The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 by two UN agencies (The World Meteorological Organisation, WMO; and the UN Environment Programme, UNEP) to assess the science relating to climate change. It publishes the Climate Assessment Reports every six to seven years. The previous series of reports was the fifth assessment cycle (AR5), which were published over 2013-14. This series is part of the sixth assessment cycle (AR6).

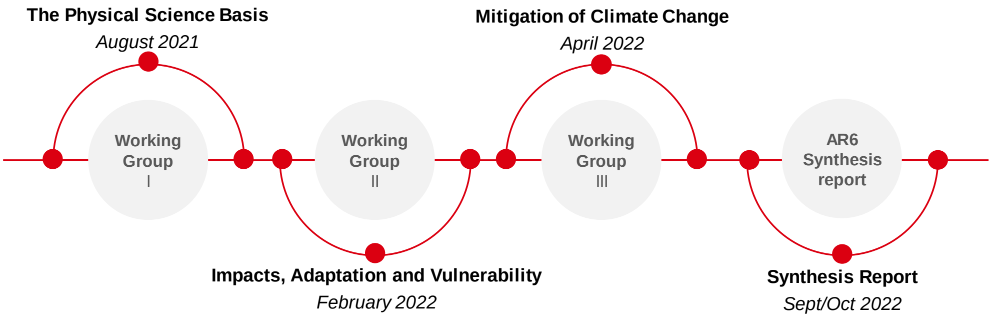
The IPCC consists of hundreds of scientists from a wide range of countries. The body does not conduct its own research but instead assesses the latest scientific papers on the topics in question. Lead authors, nominated by countries, lead reviews with many other scientists. Assessments are subject to multiple drafting and reviews before they are adopted by scientists in conjunction with governments.

Box 2: What is the Sixth Assessment or AR6?

This "Working Group I report on the Physical Science Basis" is part of the IPCC's sixth assessment cycle (AR6). This sixth assessment cycle[1] has already seen the release of three special reports and a refined methodology. The final reports will consist of:

- **Working Group 1 (WG I): *The Physical Science Basis*** (August 2021) – please see our write-up in *The twelve key points you need to know* (10 August 2021)
- **WG II: *Impacts, Adaptation and Vulnerability*** (28 February 2022) – please see our take in *The 10 points you need to know* (1 March 2022)
- **WG III: Mitigation of Climate Change** (April 2022)
- **AR6 Synthesis report** (September/October 2022)

Figure 2: The IPCC's AR6 series of reports



Source: IPCC website

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[1] https://www.ipcc.ch/assessment-report/ar6/

Box 3: IPCC terminology (likelihood and confidence)

The IPCC uses specific terminology in describing how it reaches a finding. These are described in terms of ‘**confidence**’ and ‘**likelihood**’. According to the IPCC, the confidence in the validity of a finding is based on “the type, amount, quality, and consistency of evidence…and the degree of agreement”. These are expressed qualitatively in the form of: very low, low, medium, high, very high – confidence. For likelihood, these indicated the “assessed likelihood of an outcome or result” (Figure 3).

Figure 3: Likelihood scale used by the IPCC

Term	Likelihood of the Outcome	Term	Likelihood of the Outcome
Virtually certain	99-100% probability	About as likely as not	33 to 66% probability
Very likely	90-100% probability	Unlikely	0-33% probability
Likely	66-100% probability	Very unlikely	0-10% probability
More likely than not	50-100% probability	Exceptionally unlikely	0-1% probability

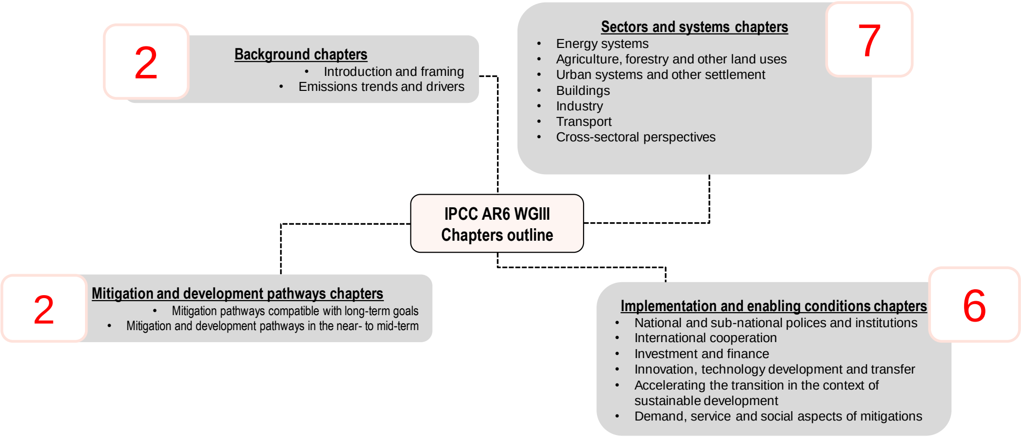
Source: IPCC AR6 methodology

A compendium of eight years of climate science

This WG III report is a compendium of updated climate science since the last report (AR5) in 2013. It incorporates more observations, more advanced climate modelling and touches more regions. The report had some 278 authors from 65 countries, of whom 29% were female, 41% were from developing countries, and 47% were new to the IPCC process.

The full report is over 2,900 pages in total, although there is a *Summary for Policymakers* (SPM) that summarises the key messages.

Figure 4: Chapter outline of the WG III full report



Source: IPCC, AR6, WG III

Essential background on scenarios and pathways

In WG III, the IPCC chose to categorise projected models (i.e. real models) into eight categories that summarise the projected emissions and temperature rises along with the associated emissions projects. Note, these are *projected* pathways (based on models), and differ from *illustrative* pathways, which are designed to show the assumptions behind them.

Figure 5: Scenario categories used by the IPCC (and required emission reductions)

		GHG emission reductions from 2019		
Category	**Temperature limit, with probability**	**2030**	**2040**	**2050**
C1	1.5°C, >50% (with no/limited overshoot)	43%	69%	84%
C2	1.5°C, >50% (with high overshoot)	23%	55%	75%
C3	2°C, >67%	21%	46%	64%
C4	2°C, >50%	10%	31%	49%
C5	2.5°C, >50%	6%	18%	29%
C6	3°C, >50%	2%	3%	5%
C7	4°C, >50%	-11%	-19%	-24%
C8	>4°C, >50%	-20%	-35%	-46%

Source: IPCC, AR6, WG III, SPM

There are always thousands of models based on myriad assumptions which feed into climate science. WG III chose five Illustrative Mitigation Pathways (IMPs) "to illustrate a range of different mitigation strategies that would be consistent with different warming levels. The IMPs illustrate pathways that achieve deep and rapid emissions reductions through different combinations of mitigation strategies."

Figure 6: Illustrative Mitigation Pathways (IMPs) used in WG III are based on different development assumptions

IMP scenario	General char.	Policy	Innovation	Energy	Land use, food biodiversity	Lifestyle
Neg (Net negative CO_2)	Mitigation in all sectors also includes a heavy reliance on net negative emissions (supply-side)	Successful international climate policy regime with a focus on a long- term temperature	Further development of CDR options	CDR, transport H2/Elec based on negative emissions	Afforestation/reforestation, BECCS, increased competition for land	Not critical – some induced via price increases
Ren (Renewable electricity)	Rapid deployment and technology development of renewables; electrification	Successful international climate policy regime; policies and financial incentives favouring renewable energy	Rapid further development of innovative electricity technologies and policy regimes	Renewable energy, electrification; sector coupling; storage or power-to-X technologies; better interconnections		Service provisioning and demand changes to better adapt to high RE supply
LD (Low-energy demand)	Reduced demand leads to early emission reductions		Social innovation; efficiency; across all sectors	Demand reduction; modal shifts in transport; rapid diffusion of BAT in buildings and industry	Lower food and agricultural waste; less meat-intensive lifestyles	Service provisioning and demand changes; behavioral changes
GS (General strengthening)	Mitigation action is **gradually strengthened** until 2030 compared to NDCs	Until 2030, primarily current NDCs are implemented – but move towards strong, universal regime >2030		Similar to Sup, but with some delay.	Similar to Sup, but with some delay.	
SP (Sustainable development)	***Shifting pathways.*** Major transformations shift development towards sustainability and reduced inequality, including deep GHG emissions reduction	SDG policies in addition to climate policy (poverty reduction; environmental protection)		Demand reduction; renewable energy	Lower food and agricultural waste; less meat-intensive lifestyles; afforestation.	Service provisioning and demand changes

Source: IPCC, AR6, WG III, SPM

Ten key findings from the IPCC's AR6 WG III

1. We are headed for 3.2°C of warming without immediate action

The IPCC finds that current policies (as of end 2020) put us on track for a "median global warming of 3.2 [2.2 to 3.5] °C by 2100". While there has been very modest improvement since the end of 2020, the implementation of policies has not been deep or quick enough to reduce projected temperature rises.

3.2°C

Median projected warming by 2100

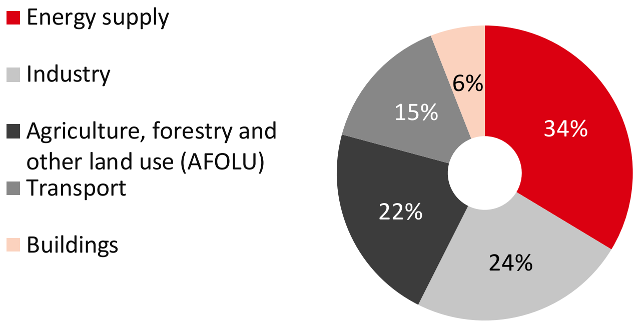
Net zero pathways are being pushed further into the future

The most up-to-date climate models show that: "Emissions have risen since 2017", "higher projected emissions by 2030", and "later dates for reaching net zero". Together, this means that the likelihood of limiting warming to 1.5C is lower than in 2018 when the Special Report on 1.5°C was released.

2. Emissions are growing; the rate of growth is slowing but is uneven across sectors

Emissions growth in the 2010-19 decade was 1.3% per year, lower than the 2.1% per year for the 2000-09 decade (*high confidence*). In absolute terms, "global net anthropogenic GHG emissions were 59±6.6 GtCO$_2$eq in 2019", which is **12% higher than 2010** (6.5 GtCO$_2$eq) and **54% higher than 1990** (21 GtCO$_2$eq).

Figure 7: 2019 net anthropogenic GHG emissions



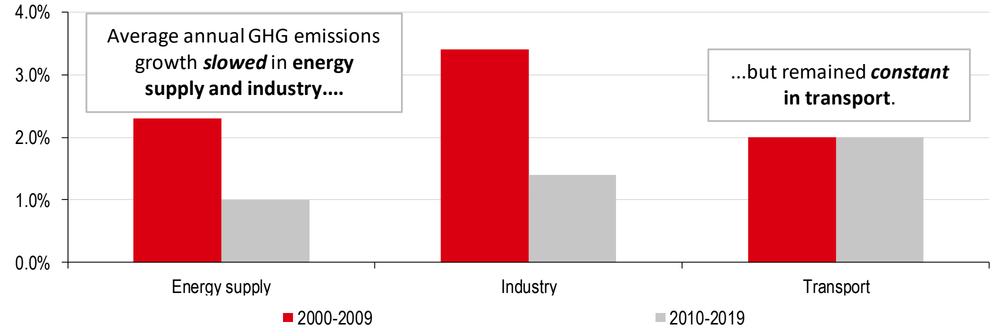
If energy emissions are attributed to the final users, 90% of emissions from electricity and heat production are allocated to **industry** and **building** sectors

Source: IPCC, AR6, WG III, SPM

Efficiency gains have been offset by growth in global activity

However, "net anthropogenic GHG emissions have increased since 2010 across all major sectors globally." The efficiencies gained from "improvements in energy intensity of GDP and carbon intensity of energy, have been less than emissions increases from rising global activity levels in industry, energy supply, transport, agriculture and buildings. (*high confidence*)".

Figure 8: Growth in emissions is uneven across sectors



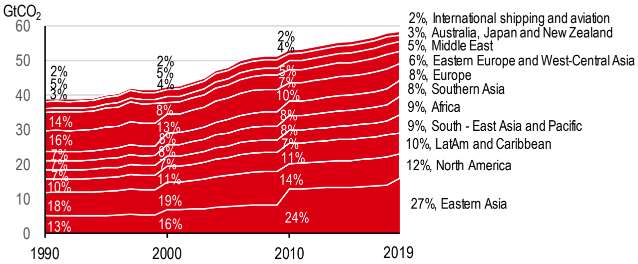
Source: IPCC, AR6, WG III, SPM

Taken as a whole, the share of emissions "attributed to urban areas" has increased to 67-72% of global emissions in 2020, up from 62% in 2015. "The drivers of urban GHG emission are complex and include population size, income, state of urbanisation and urban form. (*high confidence*)".

3. There are wide regional disparities in emissions contribution and consumption

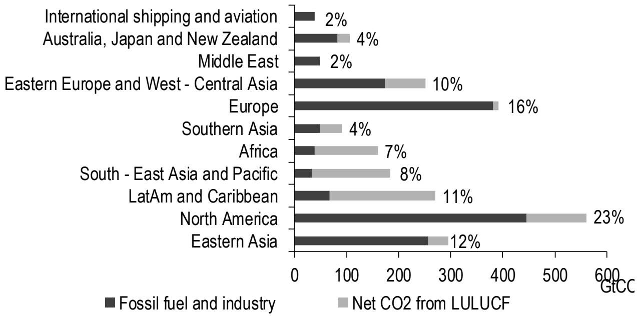
The contributions to global emissions vary widely by region and economic development. For example, per capita emissions range from 2.6-19tCO_2eq with two-fifths of the world living "in countries emitting less than 3 tCO_2eq per capita." These population groups currently "lack access to modern energy services" but the IPCC finds that improvements in living standards "can be achieved without significant global emissions growth." In other words, sustainable development can be achieved on a low emission pathway.

Figure 9: Global net anthropogenic GHG emissions by region (1990-2019)



Source: IPCC, AR6, WG III, SPM

Figure 10: Cumulative net anthropogenic CO_2 emissions per region (1850-2019)



Source: IPCC, AR6, WG III, SPM

At the same time, it is recognised that where emissions are produced is not where they are consumed. Some regions, such as North America, consume more than their ‘fair share’, so to speak.

Figure 11: Emissions are not evenly spread across the world

	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
Share of global population (2019)	17%	2%	19%	4%	8%	8%	3%	5%	9%	24%
% GHG contributions (based on net GHG 2019)	9%	3%	27%	6%	8%	10%	5%	12%	9%	8%
Relative GHG contribution vs population	*Below*	*Above*	*Above*	*Above*	*Average*	*Above*	*Above*	*Above*	*Average*	*Below*
Production-based emissions (tCO_2-FFI 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_2-FFI per person, based on 2018 data)	0.84	11	6.7	6.2	7.8	2.8	7.6	17	2.5	1.5
Relative consumption vs production	*Below*	*Above*	*Below*	*Below*	*Above*	*Average*	*Below*	*Above*	*Average*	*Average*

Source: HSBC (based on IPCC, AR6, WG III, WPM). Note: CO_2-FFI is CO_2 emissions from fossil fuels and industry.

4. The carbon budget is finite and is running out more quickly

The carbon budget is an estimation of how much CO_2 can be emitted yet staying within a reasonable chance of limiting warming to specific temperature increases. The numbers were updated in WG I and have been tweaked slightly for WG III. The historical cumulative figure (1850-2019) has been updated to 2400±240 $GtCO_2$ (*high confidence*). Some 42% of the budget was consumed over the last 30 years (1990-2019), compared with the 58% consumed in the prior 140 years (1850-1989).

Figure 12: Estimated remaining carbon budget against different temperatures limits

Approx. global warming until temperature limit	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) Based on likelihood of limiting global warming to temperature limit				
(Relative to 1850-1900)	**17%**	**33%**	**50%**	**67%**	**83%**
1.5°C	900	650	500	400	300
1.7°C	1450	1050	850	700	550
2.0°C	2300	1700	1350	1150	900

Notes: Higher or lower reductions in accompanying non-CO2 emissions can change the remaining carbon budget by 220 GtCO2 or more
Source: IPCC, AR6, WGI & WG III

5. Current fossil fuel use and infrastructure would exceed the carbon budget

Continued fossil fuel use requires abatement

The IPCC finds that “the largest growth in absolute emissions occurred in CO_2 from fossil fuels and industry”. Continued use of fossil fuels without additional abatement would exceed the carbon budget. “Estimated cumulative future CO_2 emissions from existing fossil fuel infrastructure, the majority of which is in the power sector” are roughly 660 [460–890] $GtCO_2$ – corresponding to the 33% chance of 1.5°C. However, once “unabated emissions from currently planned infrastructure in the power sector is included”, this rises to 850 [600–1100] $GtCO_2$ – corresponding to the 50% chance of hitting 1.7°C.

> “ **Net-zero CO_2 energy systems entail: a substantial reduction in overall fossil fuel use, minimal use of unabated fossil fuels, and use of CCS in the remaining fossil system**
>
> **IPCC, AR6, WG III, SPM**

"A substantial reduction in overall fossil fuel use" is required for "net-zero CO_2 energy systems" and these should involve "minimal use of unabated fossil fuels, and use of CCS in the remaining fossil system". Various modelled pathways show significant declines in fossil fuel use are required, but these are slightly different for coal, oil and gas.

Figure 13: Rapid declines of fossil fuels are required under all scenarios

	Projected decline in global use by 2050 as compared to 2019		
Warming limit scenarios	Coal	Oil	Gas
1.5°C, >50%, no overshoot	95%	60%	45%
1.5, >50%, no overshoot, without CCS	100%	60%	70%
2°C, >67%	85%	30%	15%

Source: IPCC, AR6, WG III, SPM

Interestingly, the IPCC finds, with (*medium confidence*), that to limit warming to 2°C, the "combined global discounted value of the unburned fossil fuels and stranded fossil fuel infrastructure has been projected to be around [USD] 1-4 trillion dollars from 2015 to 2050" and higher for 1.5°C.

6. Non-CO_2 emissions such as methane have a large part to play

Other non-CO_2 GHGs should not be forgotten

Although the focus tends to be on CO_2, most scenarios and models also look at non-CO_2 emissions and especially their effect over the nearer term. In other words, even reducing CO_2 emissions to net zero would still leave a substantial amount of other non-CO_2 GHGs. Hence, the IPCC finds that reducing non-CO_2 emissions could lower "peak global warming".

Projections show that even if CO_2 emissions reach net zero, non-CO_2 emissions would still be at a level consistent with a 2°C pathway (>67%). In other words, not enough work is being done to reduce these non-CO_2 emissions with methane (CH_4) the largest "(60% [55–80%]), followed by N_2O (30% [20–35%]) and F gases (3% [2–20%])".

> **"Deep GHG emissions reductions by 2030 and 2040, particularly reductions of methane emissions, lower peak warming…. and lead to less reliance on net negative CO_2 emissions**
>
> **IPCC, AR6, WG III, SPM**

This means reducing GHG in all sectors is vitally important.

7. All sectors must decarbonise but doing less in one means compensating in another

Decarbonisation involves the whole economy

The IPCC finds that all modelled pathways "involve rapid and deep and in most cases immediate GHG emission reductions in all sectors." The exact cuts required of each sector vary between pathways and warming levels but, importantly, "Doing less in one sector needs to be compensated by further reductions in other sectors if warming is to be limited. (*high confidence*)".

Energy – Decarbonising energy requires "a substantial reduction in overall fossil fuel use, the deployment of low-emission energy sources, switching to alternative energy carriers, and energy efficiency and conservation." The IPCC considers this achievable because of the significant declines in costs of renewables and their rapid deployment since 2010.

> **The continued installation of unabated fossil fuel infrastructure will 'lock-in' GHG emissions. (*high confidence*)**
>
> **IPCC, AR6, WG III, WPM**

Cities can offer strong reduction opportunities if carefully planned

Urban areas and cities – Emissions attributed to urban areas are now well over two-thirds of global emissions. However, with this concentration of assets come "opportunities to increase resource efficiency and significantly reduce GHG emissions through the systemic transition of infrastructure and urban form". These needs to be carefully considered by policymakers, according to the IPCC, and also be inclusive of a wide range of stakeholders. The IPCC puts mitigation efforts for urban areas into "three broad mitigation strategies", which "have been found to be effective when implemented concurrently:

i. reducing or changing energy and material use towards more sustainable production and consumption;

ii. electrification in combination with switching to low-emission energy sources; and

iii. enhancing carbon uptake and storage in the urban environment, for example through bio-based building materials, permeable surfaces, green roofs, trees, green spaces, rivers, ponds and lakes".

The strategies are different for developing countries, where the focus is on new buildings, compared to retrofitting existing buildings for developed countries.

Transport – Modelled scenarios for the transport sector as a whole see related CO_2 emissions declining 59% by 2050 for 1.5°C (>50%) and 29% for 2°C (>67%). Mitigation strategies in transport come with "various co-benefits, including air quality improvements, health benefits, equitable access to transportation services, reduced congestion, and reduced material demand (*high confidence*)".

Transport options include electrification and fuel substitution

The IPCC discusses the decarbonisation potential of various modes of transport: electrification for land-based transport, and other fuel sources such as "sustainable biofuels, low emissions hydrogen, and derivatives (including synthetic fuels)" for aviation, shipping, and trucking. However, the IPCC finds that many of these options require "continued investments in supporting infrastructure to increase scale of deployment (*high confidence*)" as well as "production process improvements and cost reductions (*medium confidence*)".

AFOLU (agriculture, forestry and other land use) – This is a very important sector in all scenarios but also one with a large range of projections. "The largest share…. comes from the conservation, improved management, and restoration of forests and other ecosystems (coastal wetlands, peatlands, savannas and grasslands), with reduced deforestation in tropical regions".

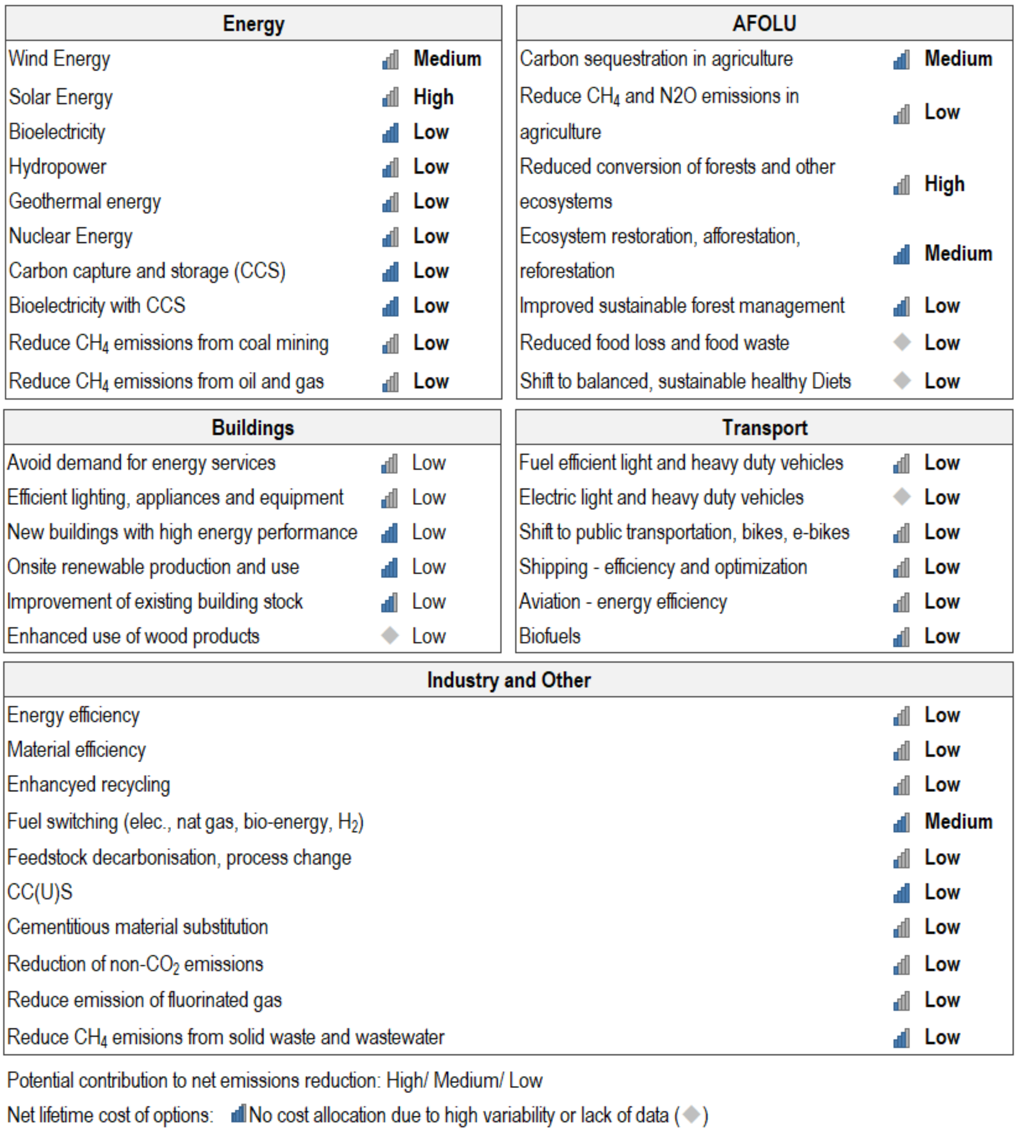
Between 2020 and 2050, around 8-14 $GtCO_2eq$ (equivalent to a fifth of global 2019 emissions) could be reduced using AFOLU options that cost below USD100 per tCO_2eq. Half of this could be achieved at less than USD20 per tCO_2eq "and could be upscaled in the near term across most regions (*high confidence*)". However, the "diversity and complexity of agricultural systems" as well as "increasing demands to raise agricultural yields, and increasing demand for livestock products" make overcoming barriers a challenge.

8. Mitigation options by sector vary with time, viability and cost

The IPCC assesses the mitigation options across sectors and the potential to reduce 2030 emissions. Some cost more than others, along with regional variations. We show a simplified version of the IPCC's findings in Figure 14. For example, Wind Energy has a 'medium' potential to reduce emissions and the costs will be quite low. The IPCC notes that "Beyond 2030, the relative importance of the assessed mitigation options is expected to change, in particular while pursuing long-term mitigation goals".

'Cost to contribution' varies across mitigation options

Figure 14: Mitigation options by sector, their costs and contribution to reductions



Energy	
Wind Energy	**Medium**
Solar Energy	**High**
Bioelectricity	**Low**
Hydropower	**Low**
Geothermal energy	**Low**
Nuclear Energy	**Low**
Carbon capture and storage (CCS)	**Low**
Bioelectricity with CCS	**Low**
Reduce CH_4 emissions from coal mining	**Low**
Reduce CH_4 emissions from oil and gas	**Low**

AFOLU	
Carbon sequestration in agriculture	**Medium**
Reduce CH_4 and N2O emissions in agriculture	**Low**
Reduced conversion of forests and other ecosystems	**High**
Ecosystem restoration, afforestation, reforestation	**Medium**
Improved sustainable forest management	**Low**
Reduced food loss and food waste	◆ **Low**
Shift to balanced, sustainable healthy Diets	◆ **Low**

Buildings	
Avoid demand for energy services	Low
Efficient lighting, appliances and equipment	Low
New buildings with high energy performance	Low
Onsite renewable production and use	Low
Improvement of existing building stock	Low
Enhanced use of wood products	◆ Low

Transport	
Fuel efficient light and heavy duty vehicles	**Low**
Electric light and heavy duty vehicles	◆ **Low**
Shift to public transportation, bikes, e-bikes	**Low**
Shipping - efficiency and optimization	**Low**
Aviation - energy efficiency	**Low**
Biofuels	**Low**

Industry and Other	
Energy efficiency	**Low**
Material efficiency	**Low**
Enhancyed recycling	**Low**
Fuel switching (elec., nat gas, bio-energy, H_2)	**Medium**
Feedstock decarbonisation, process change	**Low**
CC(U)S	**Low**
Cementitious material substitution	**Low**
Reduction of non-CO_2 emissions	**Low**
Reduce emission of fluorinated gas	**Low**
Reduce CH_4 emisions from solid waste and wastewater	**Low**

Potential contribution to net emissions reduction: High/ Medium/ Low

Net lifetime cost of options: No cost allocation due to high variability or lack of data (◆)

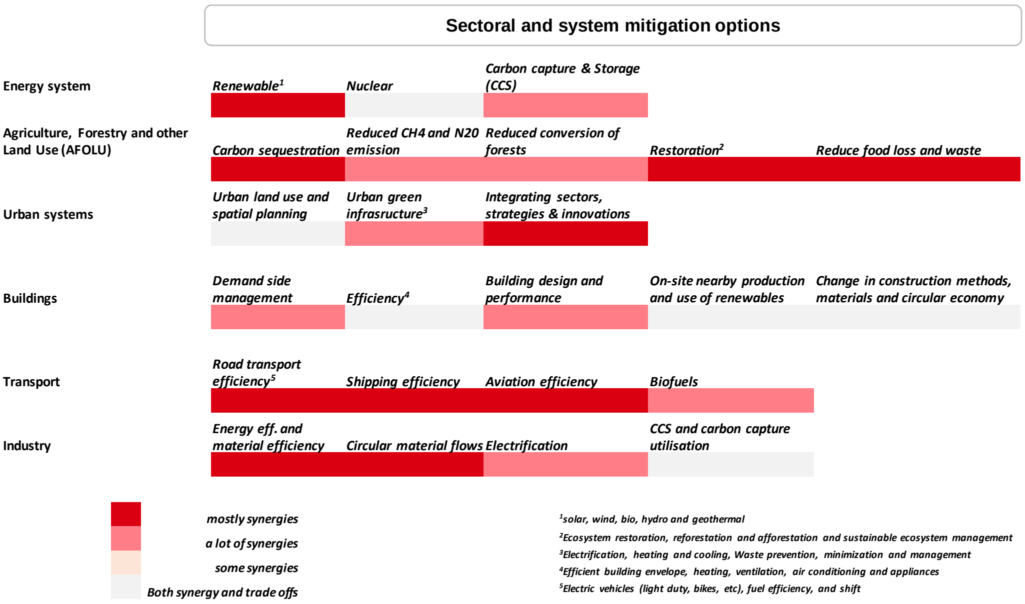
Source: IPCC, AR6, WG II, SPM (based on Figure SPM.7)

Synergies and trade-offs: The IPCC maps the options to whether there will be synergies or trade-offs with the UN's 17 Sustainable Development Goals. The report makes it clear that there should be wide stakeholder involvement as "Synergies and trade-offs depend on the development context including inequalities, with consideration of climate justice".

However, the IPCC cautions that "Climate governance is most effective when it integrates across multiple policy domains, helps realise synergies and minimize trade-offs, and connects national and sub-national policy-making levels (*high confidence*)".

Broadly speaking, there are often synergies with mitigation options

Figure 15: "The synergies and trade-offs vary dependent on context and scale."



Sectoral and system mitigation options

Energy system	Renewable[1]	Nuclear	Carbon capture & Storage (CCS)		
Agriculture, Forestry and other Land Use (AFOLU)	Carbon sequestration	Reduced CH4 and N20 emission	Reduced conversion of forests	Restoration[2]	Reduce food loss and waste
Urban systems	Urban land use and spatial planning	Urban green infrasructure[3]	Integrating sectors, strategies & innovations		
Buildings	Demand side management	Efficiency[4]	Building design and performance	On-site nearby production and use of renewables	Change in construction methods, materials and circular economy
Transport	Road transport efficiency[5]	Shipping efficiency	Aviation efficiency	Biofuels	
Industry	Energy eff. and material efficiency	Circular material flows	Electrification	CCS and carbon capture utilisation	

[1] solar, wind, bio, hydro and geothermal
[2] Ecosystem restoration, reforestation and afforestation and sustainable ecosystem management
[3] Electrification, heating and cooling, Waste prevention, minimization and management
[4] Efficient building envelope, heating, ventilation, air conditioning and appliances
[5] Electric vehicles (light duty, bikes, etc), fuel efficiency, and shift

Source: HSBC (based on IPCC, AR6, WG II, SPM, Figure SPM.8)

Demand-side strategies: The IPCC emphasises not just the mitigation options available via technology but also through "changes in infrastructure use…and socio-cultural and behavioural change." The potential is staggering. The IPCC finds that "By 2050, comprehensive demand-side strategies across all sectors could reduce CO_2 and non-CO_2 GHG emissions globally by 40-70% compared to the 2050 emissions projection".

The IPCC appeals to individuals to makes changes to demand

The regional differences highlighted in Figure 11 show that "Individuals with high socio-economic status contribute disproportionately to emissions and have the highest potential for emissions reductions, e.g., as citizens, investors, consumers, role models, and professionals. (*high confidence*)".

9. CDR is required and unavoidable but needs to be commercialized

Carbon dioxide removal: "CDR refers to anthropogenic activities that remove CO_2 from the atmosphere and store it durably in geological, terrestrial, or ocean reservoirs, or in products". For the purposes of WG III and mitigation options, the IPCC splits this into "Bioenergy with Carbon Dioxide Capture and Storage (BECCS) and Direct Air Carbon Dioxide Capture and Storage (DACCS)". The IPCC finds that BECCS has more CDR potential than DACCS across various modelled pathways. The AFOLU sector also contributes to net negative emissions.

Given the challenges of reducing emissions – especially residual emissions – in some hard-to-abate sectors, the IPCC believes that "the deployment of CDR to counterbalance hard-to-abate residual emissions is unavoidable if net zero CO_2 or GHG emissions are to be achieved."

The IPCC also finds that "CDR can fulfil three different complementary roles: lowering net CO2 or net GHG emissions in the near term; counterbalancing 'hard-to-abate' residual emissions; achieving net negative CO_2 or GHG emissions in the long term if deployed at levels exceeding annual residual emissions (*high confidence*)".

> **Currently, global rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C or 2°C.**
>
> **IPCC, AR6, WG III, SPM**

10. Economic benefits outweigh the costs, financial support is essential

The IPCC included various estimates on the costs and benefits of addressing climate change, however, these do not include overarching, future aggregates, but rather estimates relative to projected GDP. For example, “The aggregate effects of climate change mitigation on global GDP are small compared to global projected GDP growth”.

The IPCC repeated that the benefits outweigh the costs

It adds that “Models that incorporate the economic damages from climate change find that the global cost of limiting warming to 2°C over the 21st century is lower than the global economic benefits of reducing warming”. Overall, “The global economic benefit of limiting warming to 2°C is reported to exceed the cost of mitigation in most of the assessed literature. (*medium confidence*)”.

> **The global economic benefit of limiting warming to 2°C is reported to exceed the cost of mitigation in most of the assessed literature. (*medium confidence*)**
>
> **IPCC, AR6, WG III, SPM**

Various costs of delivery: The IPCC highlights that “Mitigation options costing USD100 tCO_2eq^{-1} or less could reduce global GHG emissions by at least half the 2019 level by 2030 (*high confidence*).” However, those options that cost less than USD20 per tCO_2 account for more than half of the potential. In addition, there are some options that will lead to net cost savings.

The IPCC finds it could cost up to USD400bn per year by 2050 to sequester 5-6 $GtCO_2$ per year although with several caveats of context, “direct effects of changes” and the costs of land use change.

Finance is a critical enabler of mitigation and the transition

Investment gaps and accelerated finance: The IPCC believes that finance is a critical enabler of the low carbon transition, as well as addressing just transitions and inequality. There are large investment gaps to mitigation for all sectors but it is “widest for the AFOLU sector in relative terms and for developing countries”.

3x – 6x

Investment requirements to 2030 above current levels for 2°C or 1.5°C

However, there are also many “Barriers to the deployment of commercial finance from within the financial sector” including “inadequate assessment of climate-related risks and investment opportunities, regional mismatch between available capital and investment needs, home bias factors, country indebtedness levels, economic vulnerability, and limited institutional capacities (*high confidence*).”

The IPCC also states that “Accelerated financial support for developing countries from developed countries… is a critical enabler to enhance mitigation action and address inequities in access to finance” (*high confidence*).

Fossil fuel subsidy removal: There have been multiple calls over the years for governments to remove these subsidies. The IPCC wades into this discussion by stating that it would “improve public revenue and macroeconomic performance, and yield other environmental and sustainable development benefits”.

Many other issues are discussed in the IPCC WGII report

The report many more details for individual sectors, which include:

1. *Energy systems*
2. *Agriculture, Forestry, and Other Land Uses (AFOLU)*
3. *Urban systems and other settlements*
4. *Buildings*
5. *Transport*
6. *Industry*
7. *Demand, services and social aspects of mitigation*
8. *Investment and finance*

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