Mitigation of climate change - economic sectors and technologies

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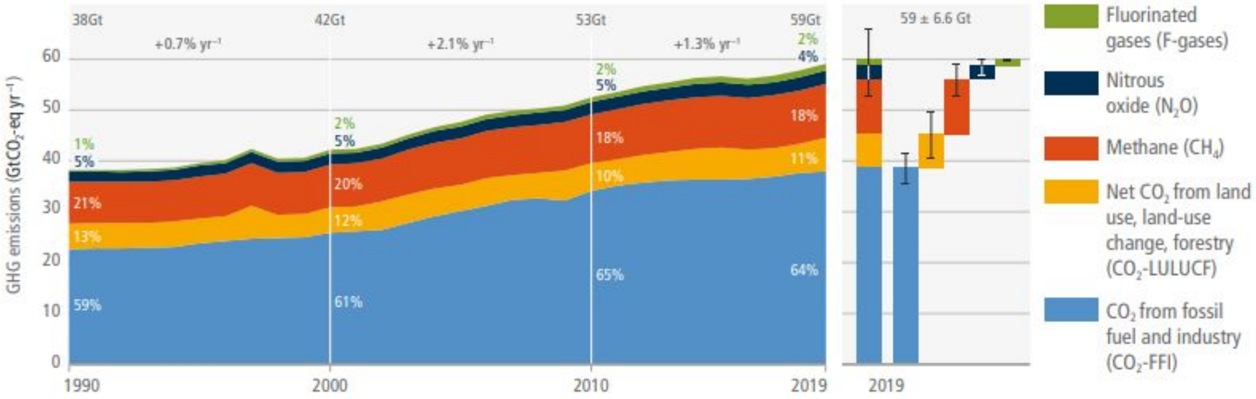
Introduction

Global net anthropogenic GHG emissions during the decade 2010–2019 were higher than any previous time in human history (high confidence).

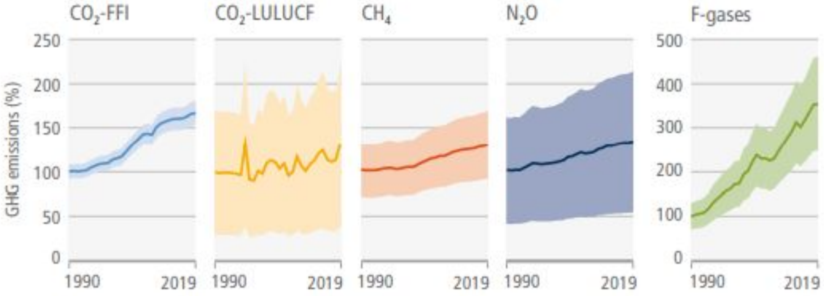
Emissions growth has varied, but has persisted, across all groups of greenhouse gases (high confidence).

GDP per capita and population growth: the strongest drivers of CO_2 emissions from fossil fuel combustion in the last decade (high confidence).

a. Global net anthropogenic GHG emissions 1990–2019 [5]

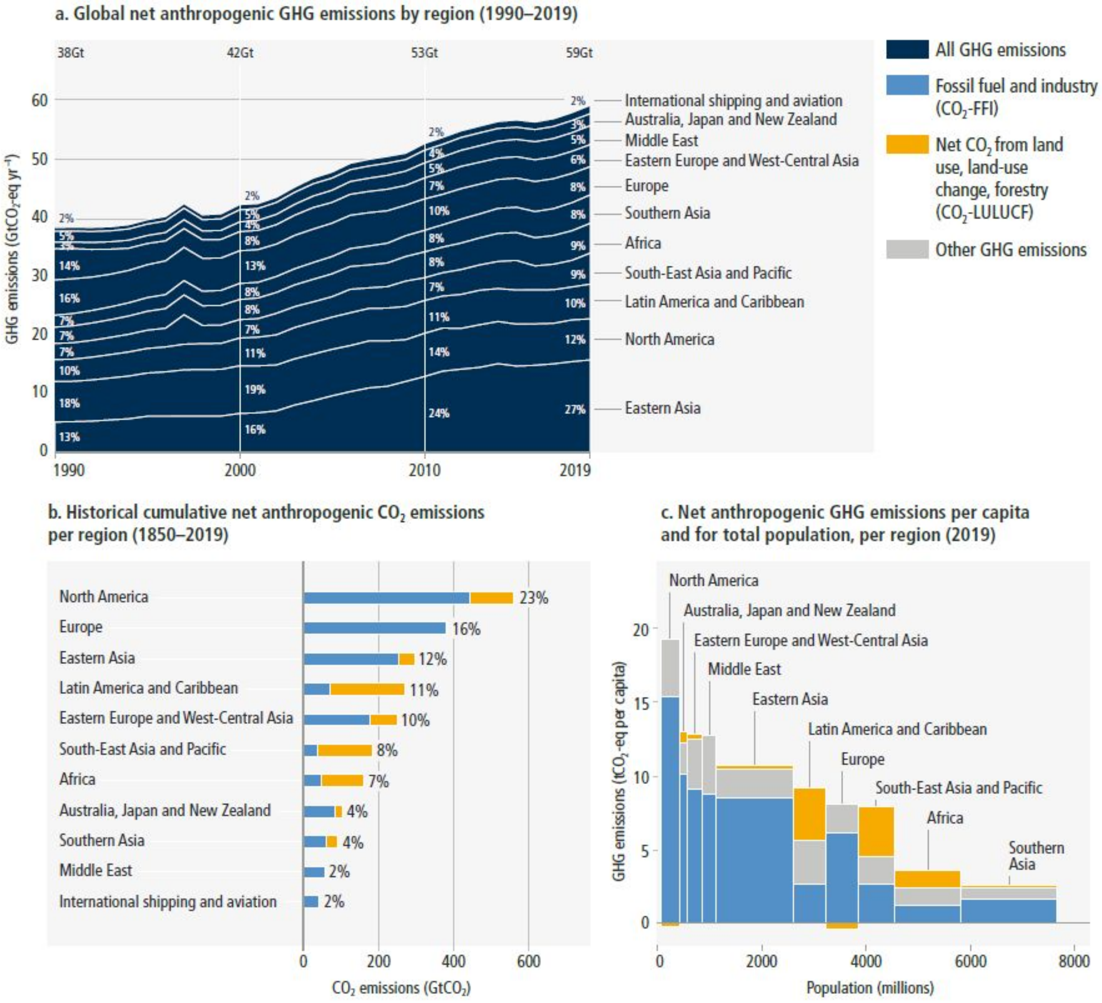


b. Global anthropogenic GHG emissions and uncertainties by gas – relative to 1990

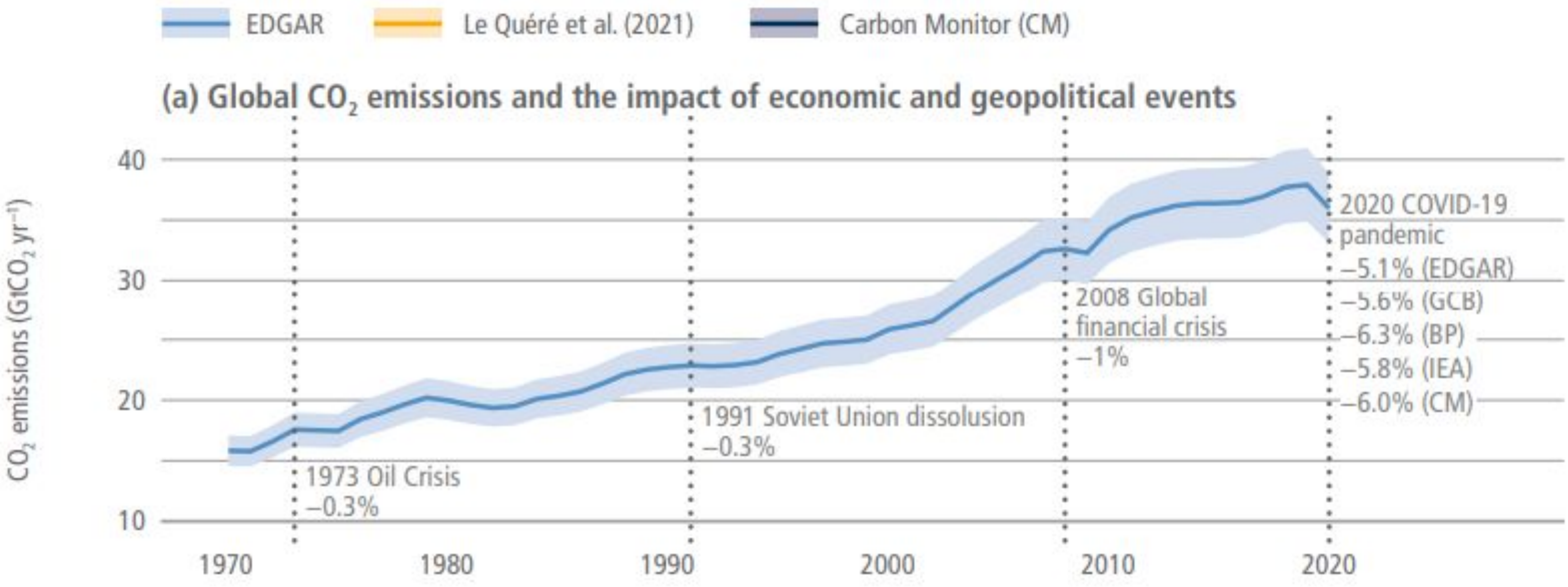


	2019 emissions ($GtCO_2$-eq)	1990–2019 increase ($GtCO_2$-eq)	Emissions in 2019, relative to 1990 (%)
CO_2-FFI	38 ± 3	15	167
CO_2-LULUCF	6.6 ± 4.6	1.6	133
CH_4	11 ± 3.2	2.4	129
N_2O	2.7 ± 1.6	0.65	133
F-gases	1.4 ± 0.41	0.97	354
Total	59 ± 6.6	21	154

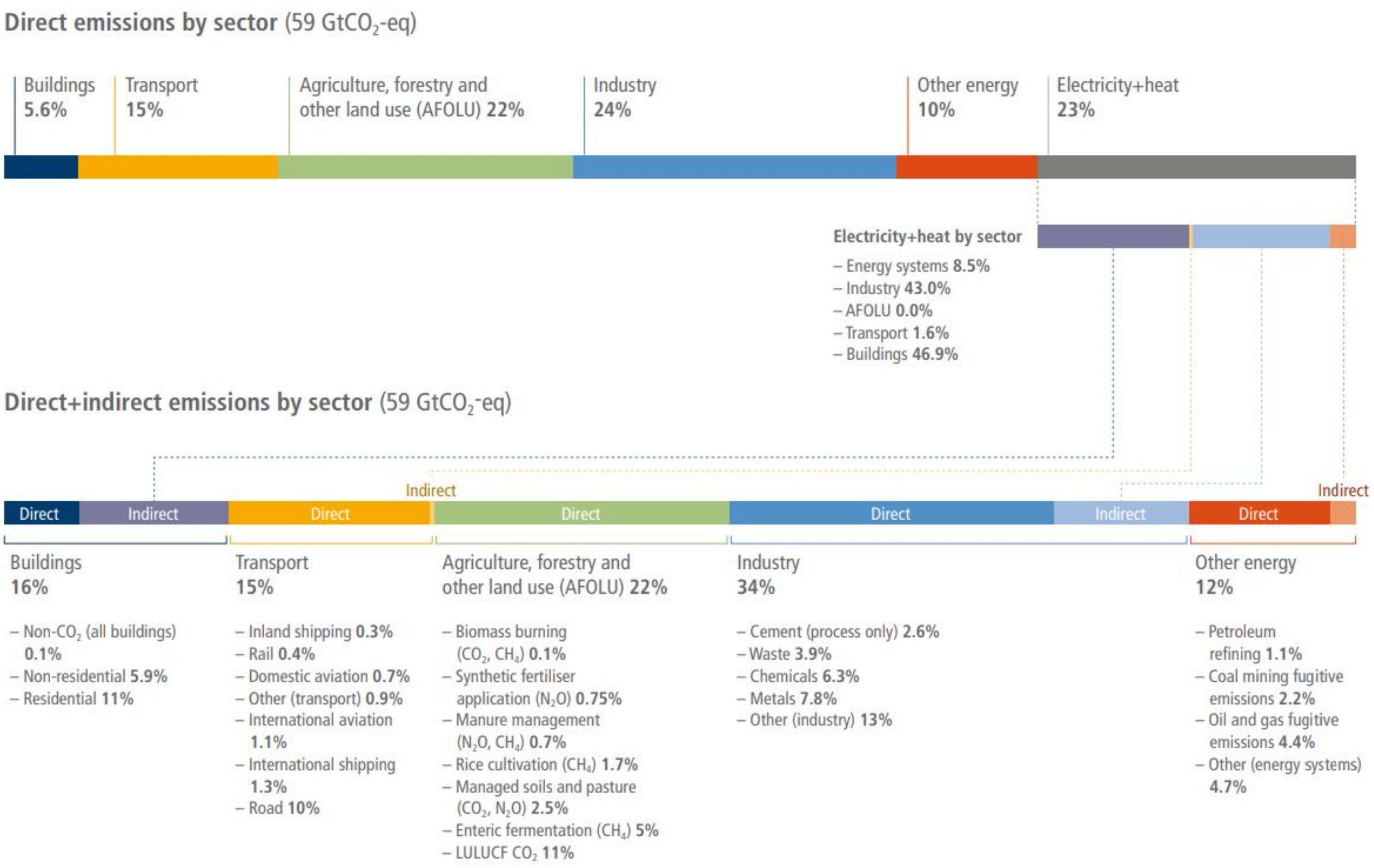
The solid line indicates central estimate of emissions trends. The shaded area indicates the uncertainty range.



a. ↑ Eastern Asia
b. Deforestation
c. Distinction between Eastern Europe and Europe


EDGAR
Le Quéré et al. (2021)
Carbon Monitor (CM)
(a) Global CO2 emissions and the impact of economic and geopolitical events
CO2 emissions (GtCO2 yr−1)
40
30
20
10
1970
1980
1990
2000
2010
2020
1973 Oil Crisis
−0.3%
1991 Soviet Union dissolution
−0.3%
2008 Global
financial crisis
−1%
2020 COVID-19
pandemic
−5.1% (EDGAR)
−5.6% (GCB)
−6.3% (BP)
−5.8% (IEA)
−6.0% (CM)

(T)

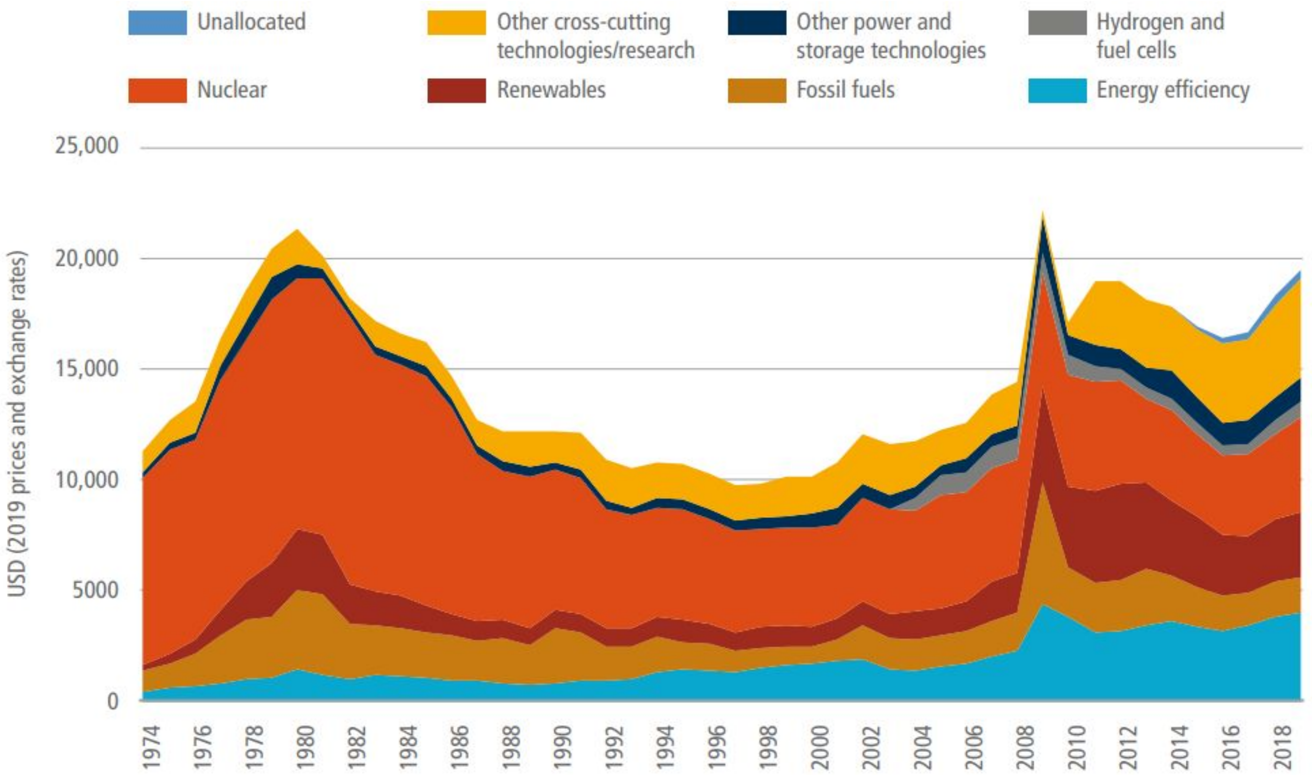


Total anthropogenic direct and indirect GHG emissions for the year 2019 (in GtCO2-eq) by sector and subsector (T)

Energy

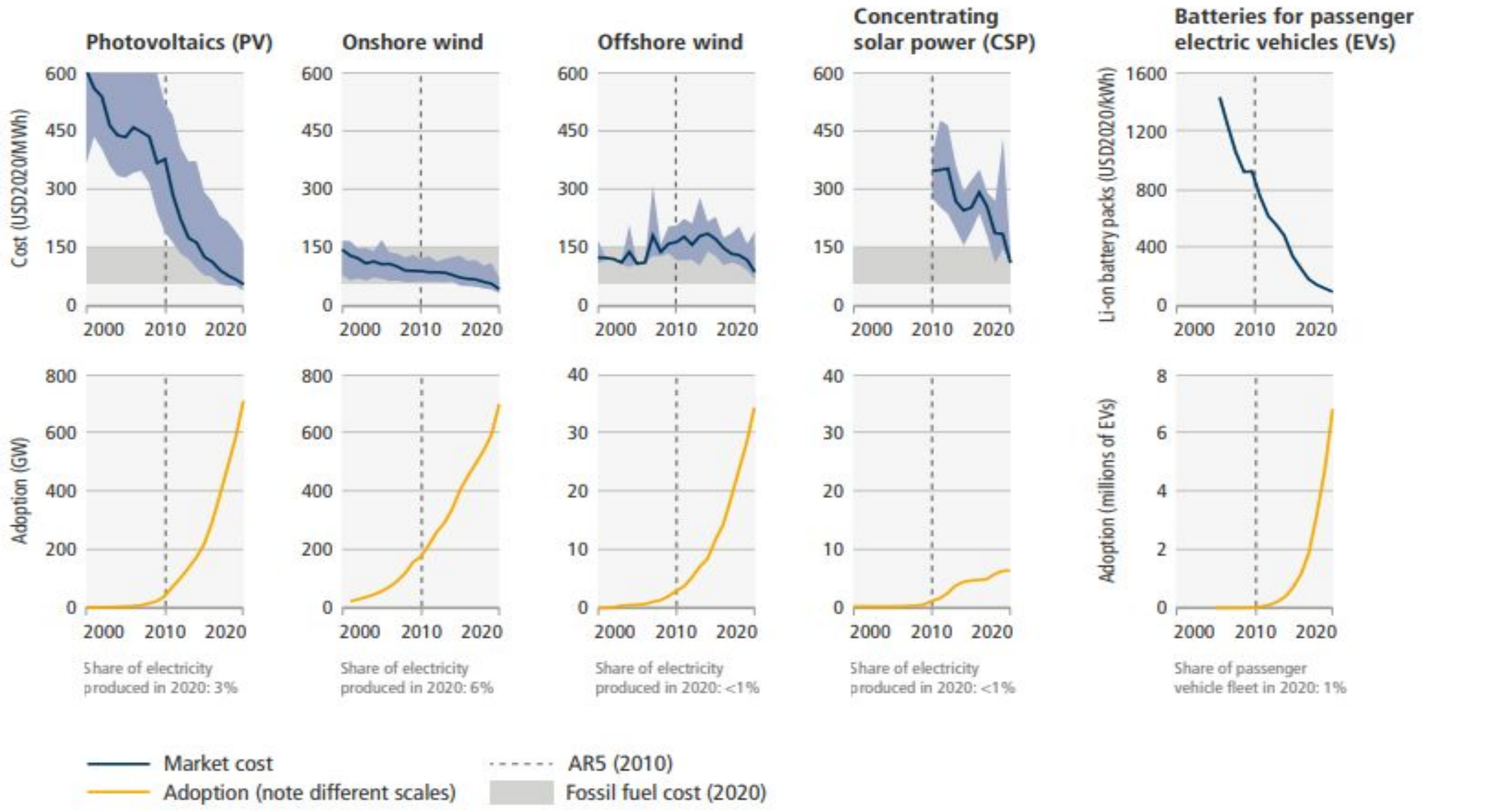
(T) Energy demands and energy sector emissions have continued to rise (high confidence).

- From 2015 to 2019, global final energy consumption grew by 6.6%
- CO_2 emissions from the global energy system grew by 4.6%, and total GHG emissions from energy supply rose by 2.7%
- Fugitive CH_4 emissions from oil, gas, and coal, accounted for 18% of GHG emissions in 2019.
- Coal electricity capacity grew by 7.6% between 2015 and 2019, as new builds in some countries offset declines in others.
- Total consumption of oil and oil products increased by 5%, and natural gas consumption grew by 15%.
- Declining energy intensity in almost all regions has been balanced by increased energy consumption.



Fraction of public energy research, development and demonstration (RD&D) spending by technology over time for IEA (largely OECD) countries between 1974 and 2018 (T)

The unit costs of some forms of renewable energy and of batteries for passenger EVs have fallen, and their use continues to rise.



Energy sector: mitigation options

(T) The unit costs for several key energy system mitigation options have dropped rapidly over the last five years, notably

- solar PV (Photovoltaics)
- wind power,
- and batteries (high confidence).

From 2015 to 2020, the costs of electricity from photovoltaics dropped 56%, wind 45%, and battery prices dropped by 64%.

Electricity from PV and wind is now cheaper than electricity from fossil sources in many regions

Electric vehicles are increasingly competitive with internal combustion engines, and large-scale battery storage on electricity grids is increasingly viable.

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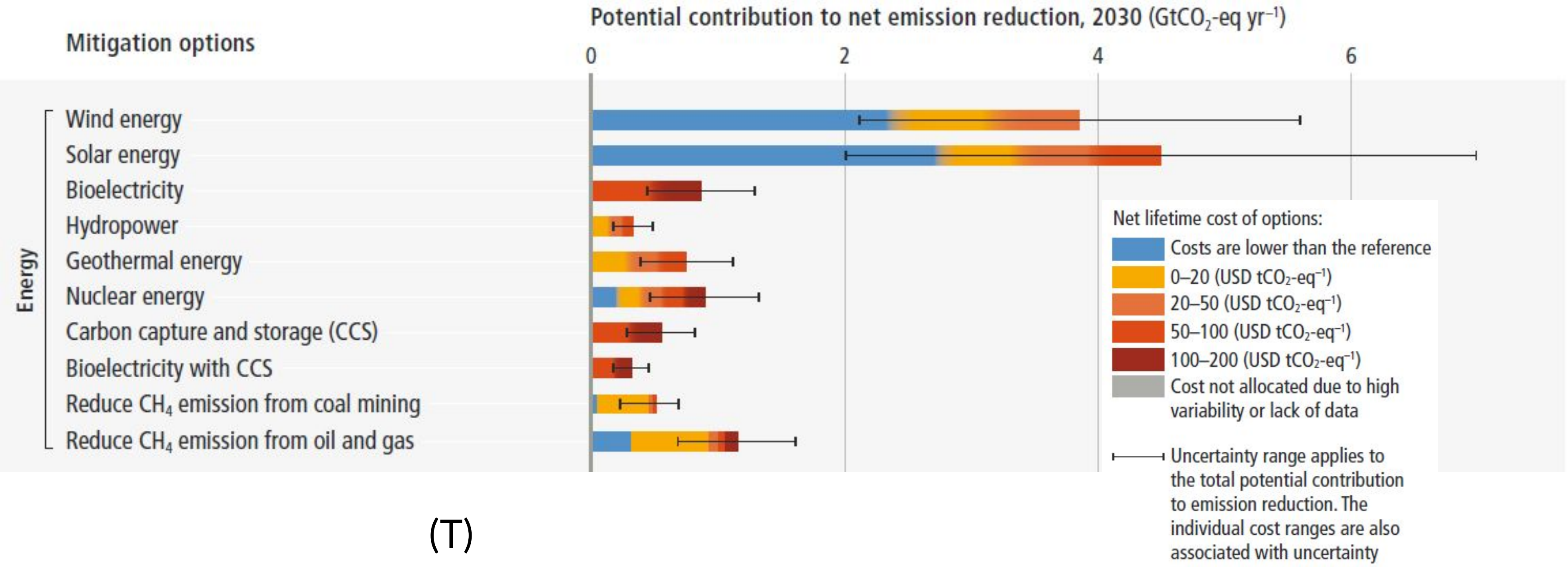

Potential contribution to net emission reduction, 2030 ($GtCO_2$-eq yr^{-1})
Mitigation options
0
2
4
6
Energy
Wind energy
Solar energy
Bioelectricity
Hydropower
Geothermal energy
Nuclear energy
Carbon capture and storage (CCS)
Bioelectricity with CCS
Reduce CH_4 emission from coal mining
Reduce CH_4 emission from oil and gas
Net lifetime cost of options:
Costs are lower than the reference
0–20 (USD tCO_2-eq^{-1})
20–50 (USD tCO_2-eq^{-1})
50–100 (USD tCO_2-eq^{-1})
100–200 (USD tCO_2-eq^{-1})
Cost not allocated due to high variability or lack of data
Uncertainty range applies to the total potential contribution to emission reduction. The individual cost ranges are also associated with uncertainty

(T)

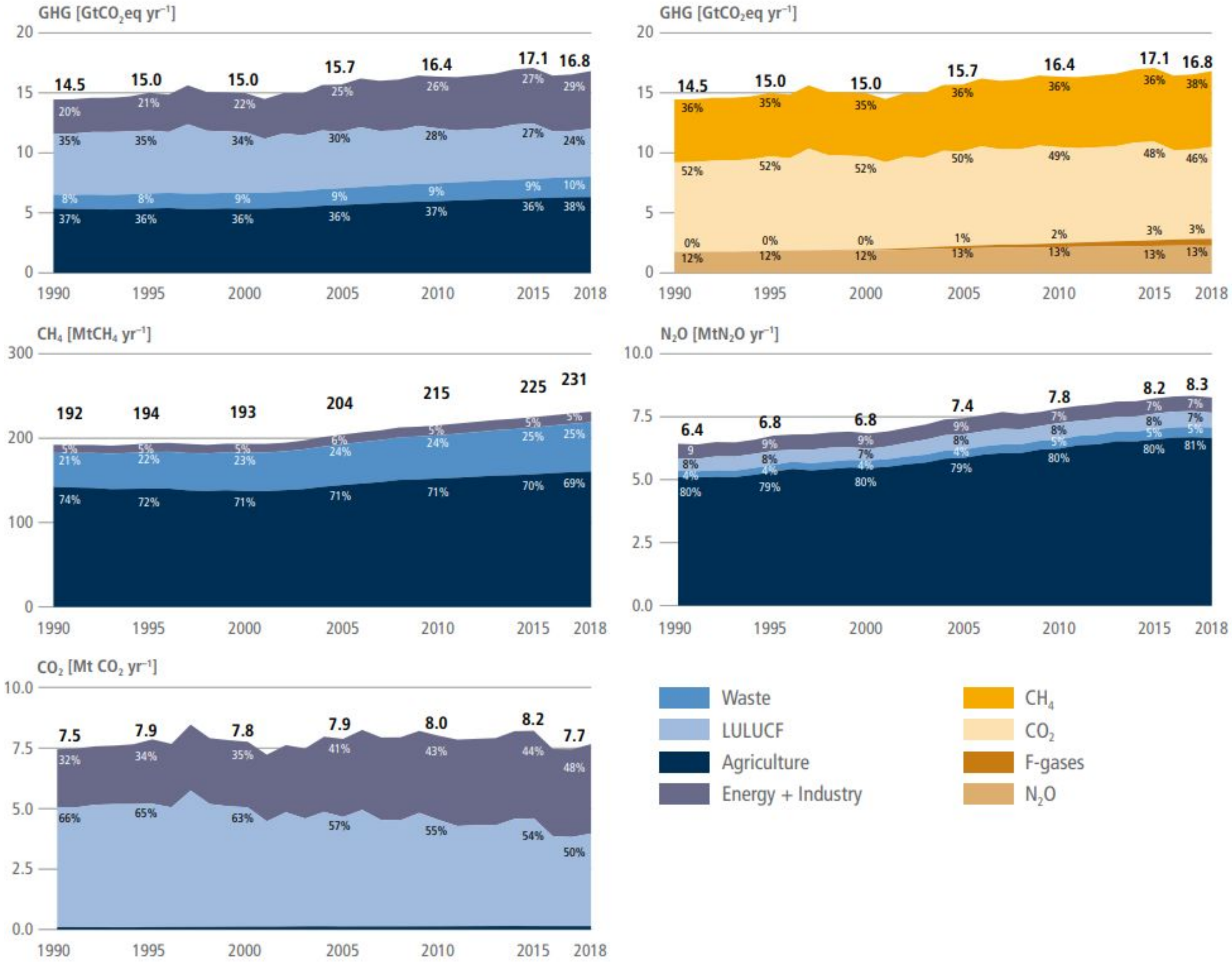
Agriculture, forestry and other land use

The AFOLU sector, on average, accounted for 13–21% of global total anthropogenic GHG emissions in the period 2010–2019. At the same time managed and natural terrestrial ecosystems were a carbon sink, absorbing around one third of anthropogenic CO_2 emissions (medium confidence).

Agriculture, forestry and other land use

Land-use change drives net AFOLU CO2 emission fluxes. The rate of deforestation, which accounts for 45% of total AFOLU emissions, has generally declined, while global tree cover and global forest-growing stock levels are likely increasing (medium confidence).

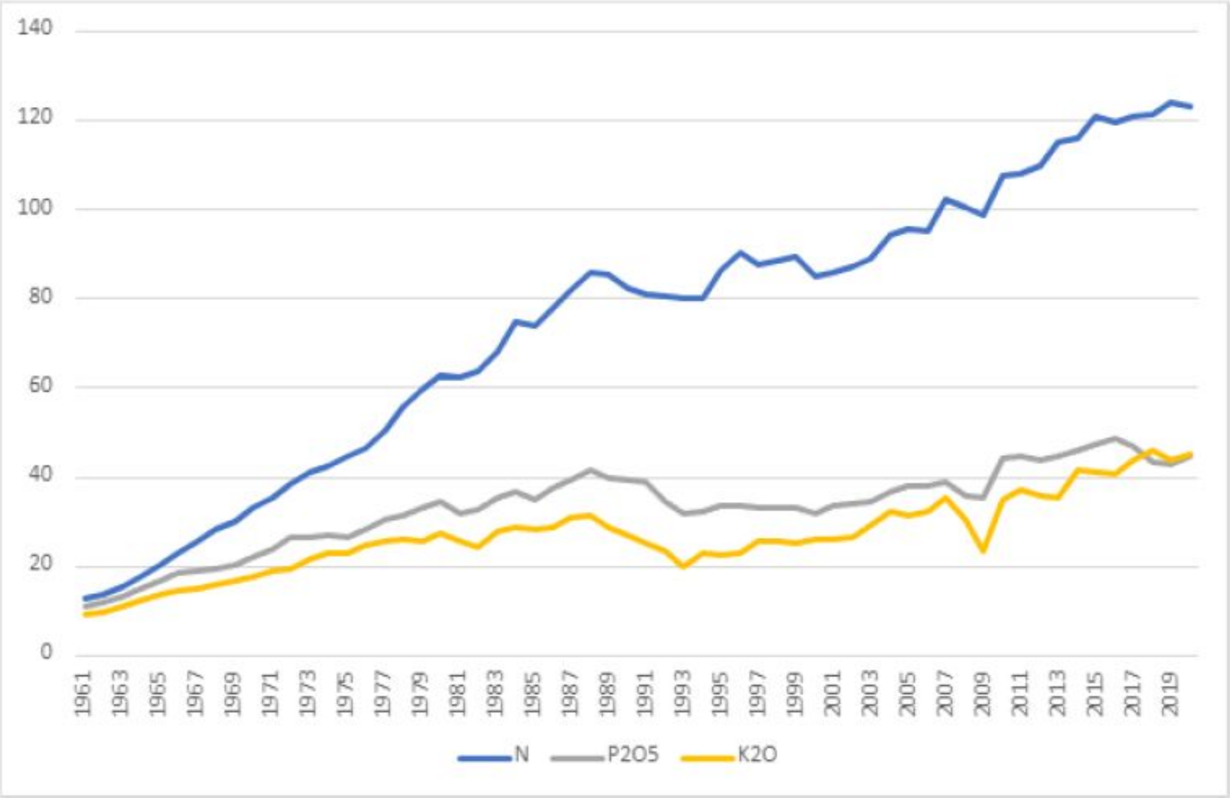
Regional differences: losses of carbon generally observed in tropical regions, gains in temperate and boreal regions.



Food-system GHG emissions from the agriculture, and land use, land-use change and forestry (LULUCF), waste, and energy and industry sectors (T)

Fertilizers industry

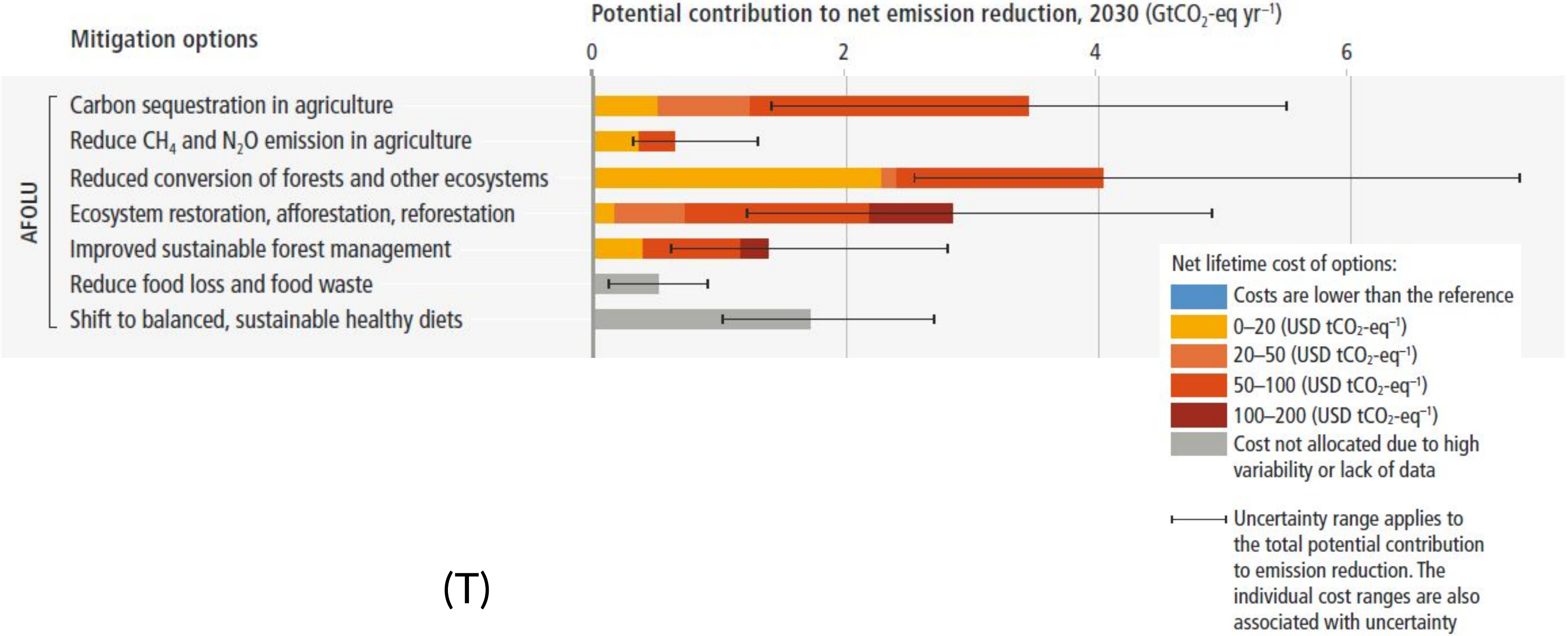
N fertilizers are produced with ammonia synthesized in Haber-Bosch process ($N_2 + 3H_2 \rightarrow 2NH_3$) requiring great amounts of fossil fuels, namely methane (substrate for the reaction) and fuel for power plants operation. In 2022, 28% of world ammonia supply was provided by China, followed by Russia responsible for 10,7%, United States' production constituted 8,7% share, whereas India's production accounted for 8% of world's supply (4).



Production of inorganic fertilizers expressed in N, P_2O_5, K_2O equivalents (3)

Fertilizers industry

With the estimated global production of ammonia amounting to 150 Tg (2, 4), the process of its synthesis makes up for **1.4% of global CO_2 emissions and 1% of the world's total energy consumption** (1). Taking into account forecasted yearly augmentation of ammonia production by 2.3% (2), further increase of energy consumption and emissions caused by this activity is unavoidable.



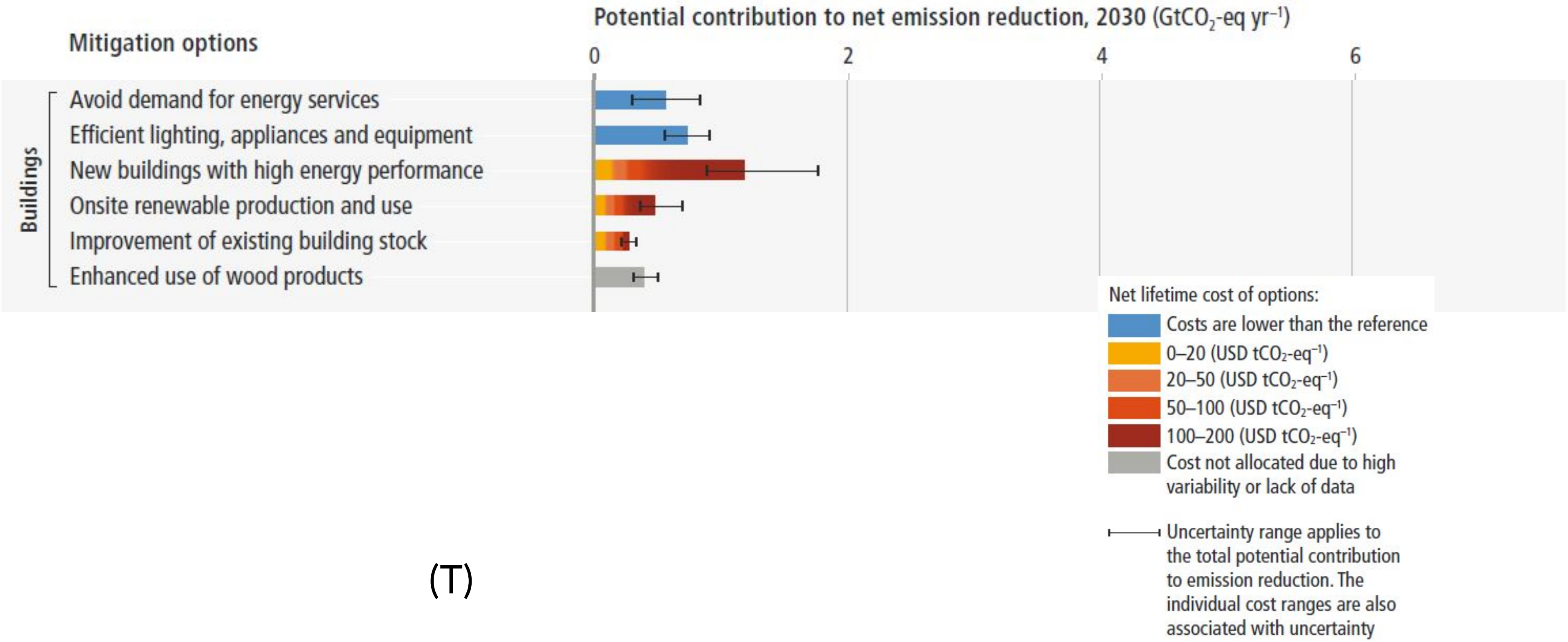
Mitigation options
Potential contribution to net emission reduction, 2030 ($GtCO_2$-eq yr^{-1})
0
2
4
6
AFOLU
Carbon sequestration in agriculture
Reduce CH_4 and N_2O emission in agriculture
Reduced conversion of forests and other ecosystems
Ecosystem restoration, afforestation, reforestation
Improved sustainable forest management
Reduce food loss and food waste
Shift to balanced, sustainable healthy diets
Net lifetime cost of options:
Costs are lower than the reference
0–20 (USD tCO_2-eq^{-1})
20–50 (USD tCO_2-eq^{-1})
50–100 (USD tCO_2-eq^{-1})
100–200 (USD tCO_2-eq^{-1})
Cost not allocated due to high variability or lack of data
Uncertainty range applies to the total potential contribution to emission reduction. The individual cost ranges are also associated with uncertainty

(T)

Buildings

(T) Global GHG emissions from buildings were 12 $GtCO_2$-eq in 2019, equivalent to 21% of global GHG emissions.

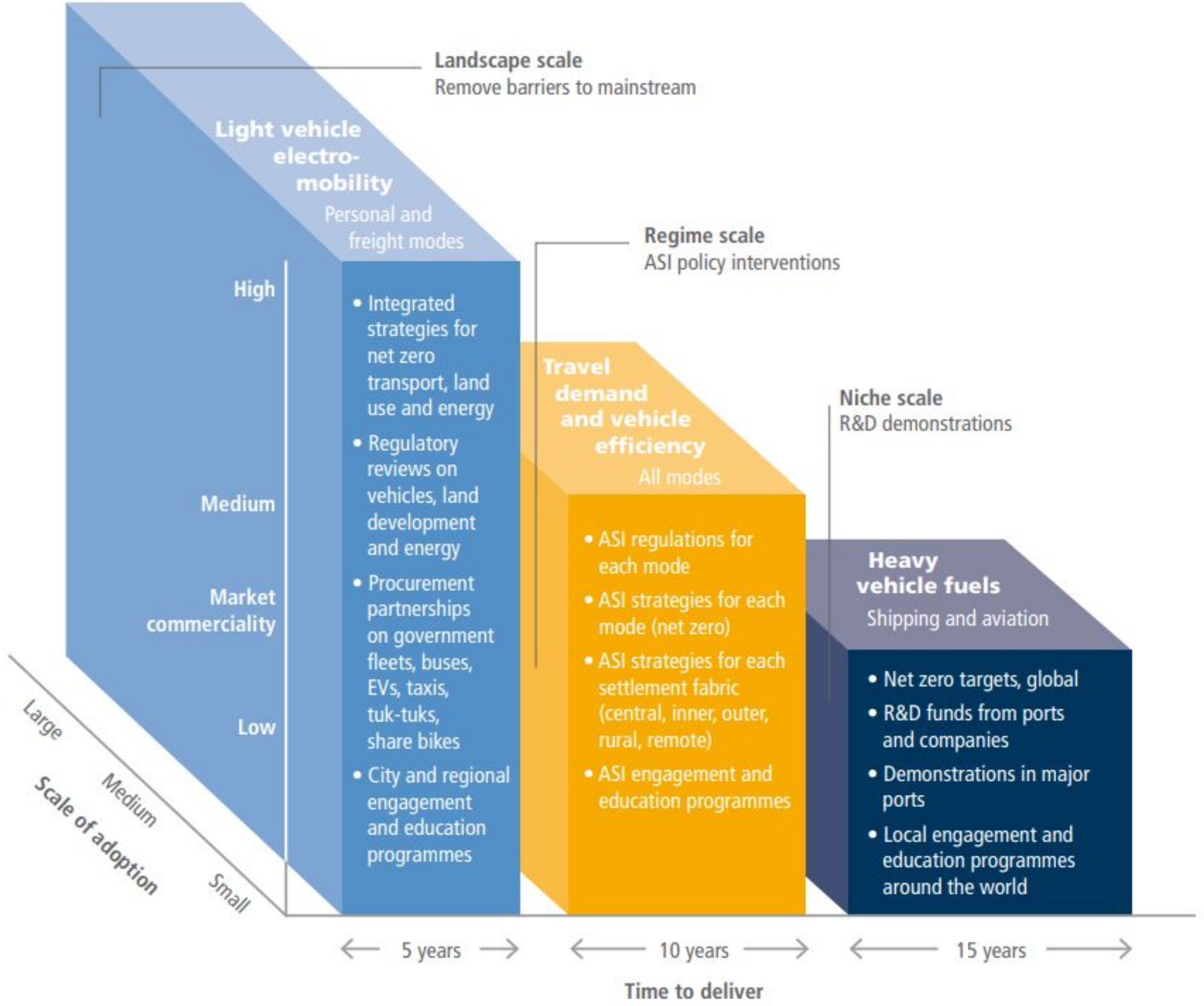
Of this, 57% (6.8 $GtCO_2$-eq) were indirect emissions from off-site generation of electricity and heat, 24% (2.9 $GtCO_2$-eq) were direct emissions produced on-site and 18% (2.2 $GtCO_2$-eq) were embodied emissions from the production of cement and steel used in buildings (high confidence).


Potential contribution to net emission reduction, 2030 ($GtCO_2$-eq yr^{-1})
Mitigation options
0
2
4
6
Buildings
Avoid demand for energy services
Efficient lighting, appliances and equipment
New buildings with high energy performance
Onsite renewable production and use
Improvement of existing building stock
Enhanced use of wood products
Net lifetime cost of options:
Costs are lower than the reference
0–20 (USD tCO_2-eq^{-1})
20–50 (USD tCO_2-eq^{-1})
50–100 (USD tCO_2-eq^{-1})
100–200 (USD tCO_2-eq^{-1})
Cost not allocated due to high variability or lack of data
Uncertainty range applies to the total potential contribution to emission reduction. The individual cost ranges are also associated with uncertainty

(T)

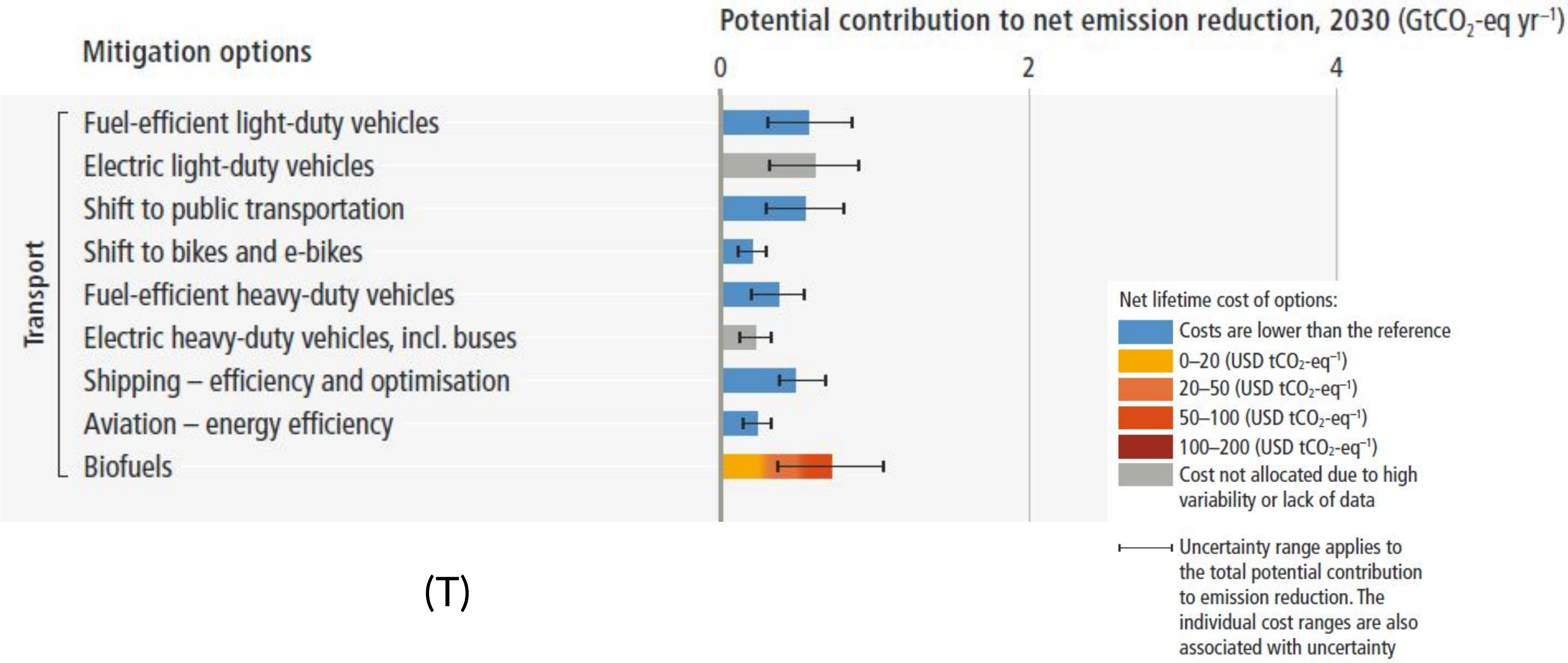
Transportation

(T) Meeting climate mitigation goals would require transformative changes in the transport sector. In 2019, direct GHG emissions from the transport sector were 8.7 $GtCO_2$-eq (up from 5.0 $GtCO_2$-eq in 1990) and accounted for 23% of global energy-related CO_2 emissions.



Mitigation options and enabling conditions for transport.

'Niche' scale includes strategies that still require innovation (T)

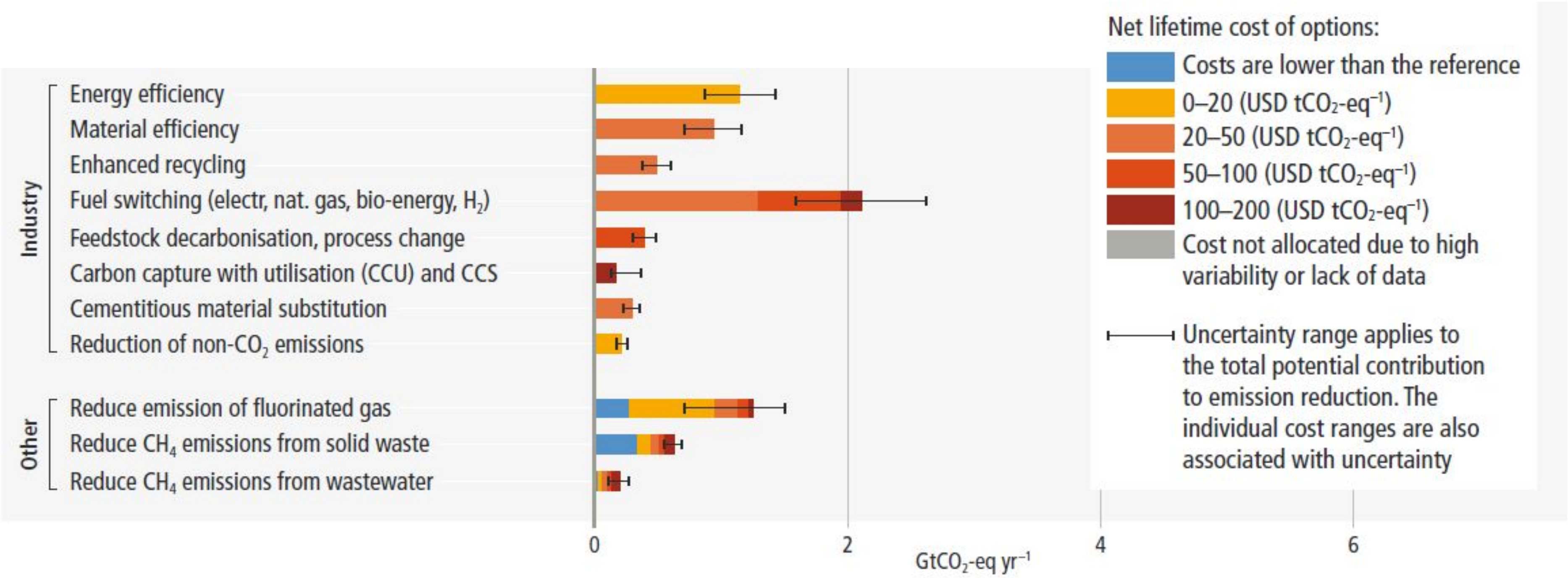

Potential contribution to net emission reduction, 2030 (GtCO2-eq yr-1)
Mitigation options
0
2
4
Transport
Fuel-efficient light-duty vehicles
Electric light-duty vehicles
Shift to public transportation
Shift to bikes and e-bikes
Fuel-efficient heavy-duty vehicles
Electric heavy-duty vehicles, incl. buses
Shipping – efficiency and optimisation
Aviation – energy efficiency
Biofuels
Net lifetime cost of options:
Costs are lower than the reference
0–20 (USD tCO2-eq-1)
20–50 (USD tCO2-eq-1)
50–100 (USD tCO2-eq-1)
100–200 (USD tCO2-eq-1)
Cost not allocated due to high variability or lack of data
Uncertainty range applies to the total potential contribution to emission reduction. The individual cost ranges are also associated with uncertainty

(T)

Industry & other

(T) GHG emissions attributed to the industrial sector originate from fuel combustion, process emissions, product use and waste, which jointly accounted for 14.1 $GtCO_2$-eq or 24% of all direct anthropogenic emissions in 2019, second behind the energy supply sector.

Industry is a leading GHG emitter – 20 $GtCO_2$-eq or 34% of global emissions in 2019 – if indirect emissions from power and heat generation are included.



Industry
Energy efficiency
Material efficiency
Enhanced recycling
Fuel switching (electr, nat. gas, bio-energy, H_2)
Feedstock decarbonisation, process change
Carbon capture with utilisation (CCU) and CCS
Cementitious material substitution
Reduction of non-CO_2 emissions
Other
Reduce emission of fluorinated gas
Reduce CH_4 emissions from solid waste
Reduce CH_4 emissions from wastewater
0
2
4
6
$GtCO_2$-eq yr^{-1}
Net lifetime cost of options:
Costs are lower than the reference
0–20 (USD tCO_2-eq^{-1})
20–50 (USD tCO_2-eq^{-1})
50–100 (USD tCO_2-eq^{-1})
100–200 (USD tCO_2-eq^{-1})
Cost not allocated due to high variability or lack of data
Uncertainty range applies to the total potential contribution to emission reduction. The individual cost ranges are also associated with uncertainty

(T)

Conclusions

- Greatest mitigation potential: solar and wind energy ($, benefits > expenditures at 2 $GtCO_2$-eq yr^{-1}), AFOLU: reduced conversion of forests and other ecosystems; carbon sequestration in agriculture; ecosystem restoration, afforestation, reforestation ($$-$$$)
- Smaller mitigation potential, but also economically feasible: fuel efficiency, public transportation, shift to bikes, optimized shipping
- If the suggested mitigations options are implemented, GHG emissions can be reduced by 50%

Sources

(1) Capdevila-Cortada, M. (2019). Electrifying the Haber–Bosch. Nature Catalysis, 2(12), 1055-1055.

(2) Food and Agriculture Organisation (FAO). (2017). World fertilizer trends and outlook to 2020. Food and Agriculture Organization of the United Nations.

(3) Food and Agriculture Statistics (FAOSTAT). (2022). Date accessed: 29.06.2023. Available online: https://www.fao.org/faostat/en/#data/RFN

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IPCC, 2023: Summary for Policymakers. In: *Climate Change 2023: Synthesis Report.* Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

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Thank you for your attention

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