# The IPCC Working Group III: Mitigation of Climate Change

A fuller summary can be found at: In-depth Q&A: The IPCC's sixth assessment on how to tackle climate change - Carbon Brief

We need to make "rapid and deep" emissions reductions, far greater than we are currently planning for if we are to succeed in reducing global heating to the safe level of 1.5ºC says the latest report of the Intergovernmental Panel on Climate Change (IPCC).

Worldwide emissions have continued to rise until now. UK emissions are falling, but this has been helped by the export of emissions related, for example, to manufacturing. The drop in emissions here has tended to be balanced by increases in emissions elsewhere.

If we are to limit warming to 1.5C with no or limited overshoot, the IPCC say we must ensure global $CO_2$ emissions peak "at the latest before 2025" and then fall to 48% below 2019 levels in 2030, reaching net-zero by the "early 2050s."

## Contents


1. The Report 2
2. Current global emissions trends 2
3. Improving current policies and pledges 3
4. Limiting warming to 1.5ºC or 2ºC 3
5. Encouraging behaviour change 4
6. Changing how food is produced and what people choose to eat 5
7. Changes needed in global energy systems 7
8. Land: emissions and potential for absorbing GHGs 8
9. Removing $CO_2$ 8
10. Solar Geoengineering 9
11. Cutting emissions in cities and buildings 9
12. Cutting transport emissions 9
13. Decarbonising Industry 12
14. Progress on policies so far 13
15. Using the Paris Agreement and developing climate finance 14
16. Paying for and benefitting from emissions cuts 14
17. Speeding up development of new ideas and technologies 16
18. Supporting sustainable development 16

# 1. The Report

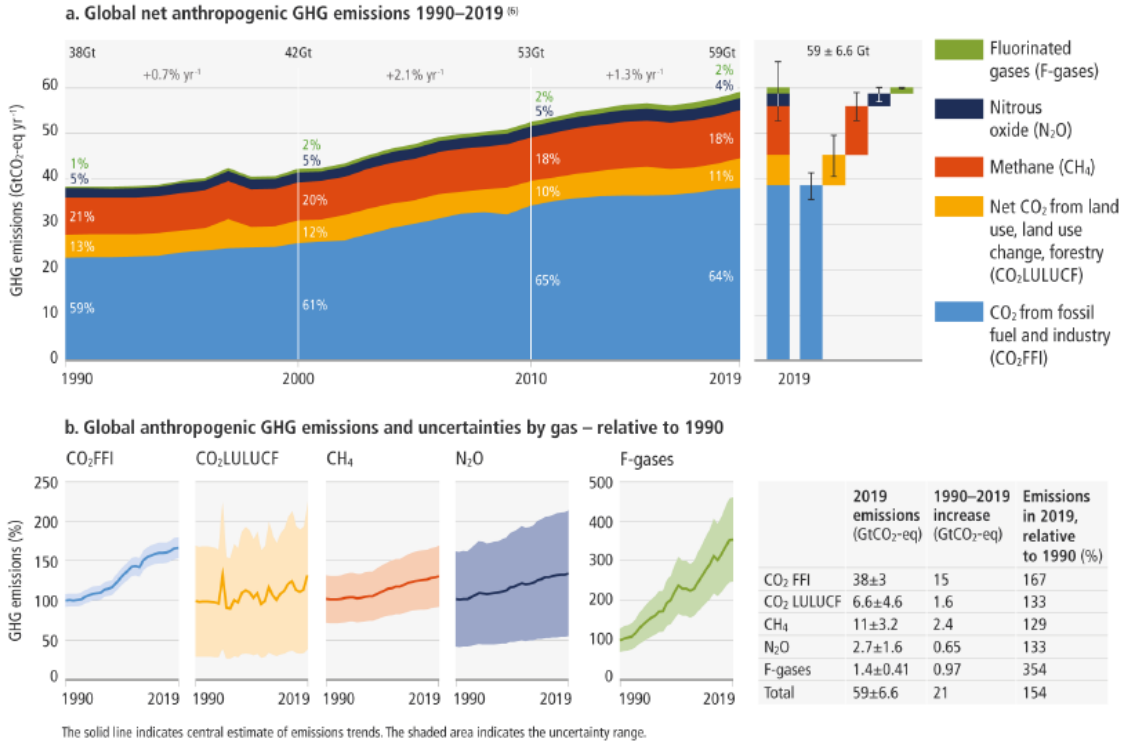
This was published on 4 April 2022, assesses the effectiveness of what has been done so far and sets out options for what needs still to be done to prevent dangerous levels of global heating. It updates earlier work and takes account of "new literature, methodological and recent developments, and changes in approaches towards climate change mitigation since the IPCC AR5 report was published in 2014."

The report is just below 3,000 pages long and its different sections will be consolidated for publication in the autumn.

# 2. Current global emissions trends

Globally, between 2010 and 2019 greenhouse gas (GHG) emissions were "higher than at any previous time in human history"

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



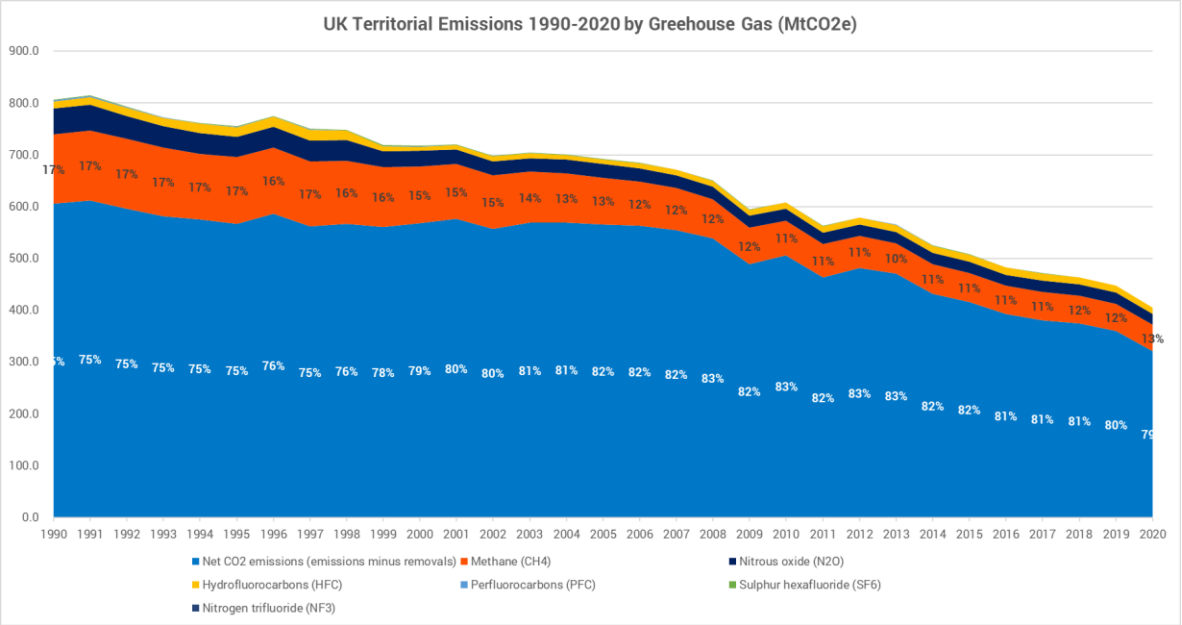

| | 2019 emissions ($GtCO_2$-eq) | 1990–2019 increase ($GtCO_2$-eq) | Emissions in 2019, relative to 1990 (%) |
|---|---|---|---|
| $CO_2$ FFI | 38±3 | 15 | 167 |
| $CO_2$ LULUCF | 6.6±4.6 | 1.6 | 133 |
| $CH_4$ | 11±3.2 | 2.4 | 129 |
| $N_2O$ | 2.7±1.6 | 0.65 | 133 |
| F-gases | 1.4±0.41 | 0.97 | 354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

Since 1990, worldwide, methane emissions have grown by 29%, nitrous oxide emissions by 33% and $CO_2$ emissions by 67%. Over the same period fluorinated gases grew from a low level by 254% and are now a significant factor.

There have been some "decarbonisation gains", and energy efficiency gains: energy needed to generate each unit of GDP has fallen by 2% per year. Even so these increased efficiencies "have been largely wiped out by increases in demand for goods and services".

There are radical differences in the pattern of emissions between countries and regions. So-called "developed countries" have more than double the per-capita emissions of Asia and the Pacific, Africa or Latin America. The lowest emissions per person are produced by least-developed countries that have "contributed only a negligible proportion of historic GHG emissions growth". The UK has a responsibility to reduce emissions rapidly

Over the same period emissions within the UK have been falling (the chart below is based on BEIS data), but this conceals the extent to which the UK benefits from emissions outside the UK in the growing of foods and manufacture of goods that the UK imports and activities funded by UK investments.




## 3. Improving current policies and pledges

The report has assessed whether current policies and pledges will reduce emissions sufficiently. IPCC cannot rule out global heating of over 4ºC if these policies are not made more stringent. Unless emissions reduce rapidly, the 1.5ºC target for global heating agreed in Paris will be beyond reach.

If current commitments are not improved on, it is likely that global temperature increase will go above 1.5ºC by between 0.15 and 0.3ºC by 2100. This means we will have to rely heavily on carbon dioxide removal, whose technology is at an early stage of development. There would be less risk of overshooting the target if emissions reductions could be made earlier than many countries have proposed.

Current nationally determined contributions will leave us with levels of emissions by 2030 that will make it difficult to limit warming to 2ºC.

## 4. Limiting warming to 1.5ºC or 2ºC

In 2018 the IPCC issued a special report on limiting global heating to 1.5ºC. This is now more difficult to achieve because of the slight increase in emissions worldwide that has occurred since then. To stay below a 1.5ºC increase global GHG emissions will have to fall to 43% below 2019

levels by 2030 and to 84% below 2019 by 2050. If these targets are not achieved, we will have to rely on additional interventions not yet developed:

- Carbon dioxide removal / direct air capture
- Biomass
- Bioenergy with carbon capture and storage

Emissions reductions pathways considered that are likely to limit global heating to 1.5ºC could reach net-zero on average around 2050 but some scenarios reach net-zero from 2035 onwards. Pathways that limit global heating to 2ºC reach net-zero between 2055 and 2070

# 5. Encouraging behaviour change

This has been a "substantial overlooked strategy." It will help reduce emissions to encourage:

- Increased use of new low-carbon technologies,
- changes in consumption patterns and preferences, and
- making more use of cleaner forms of transport.

If successful, behaviour change that reduces demand for high greenhouse gas emitting processes could obviate the need for unproven technologies such as BECCS (bioenergy with carbon capture and storage).

The report says that by 2050 changes in behaviour could cut greenhouse emissions by 40-70%

Figure 5.7 of the report gives details of the extent to which this could happen with food (approx -50%); industry (approx. – 25%), land transport (approx. – 70%); buildings (approx. – 70%); and electricity (approx. – 45%) of the increased production.

The greatest volume of greenhouse gas saving comes from changes in consumption of food (8 $GtCO_2e$) such as:

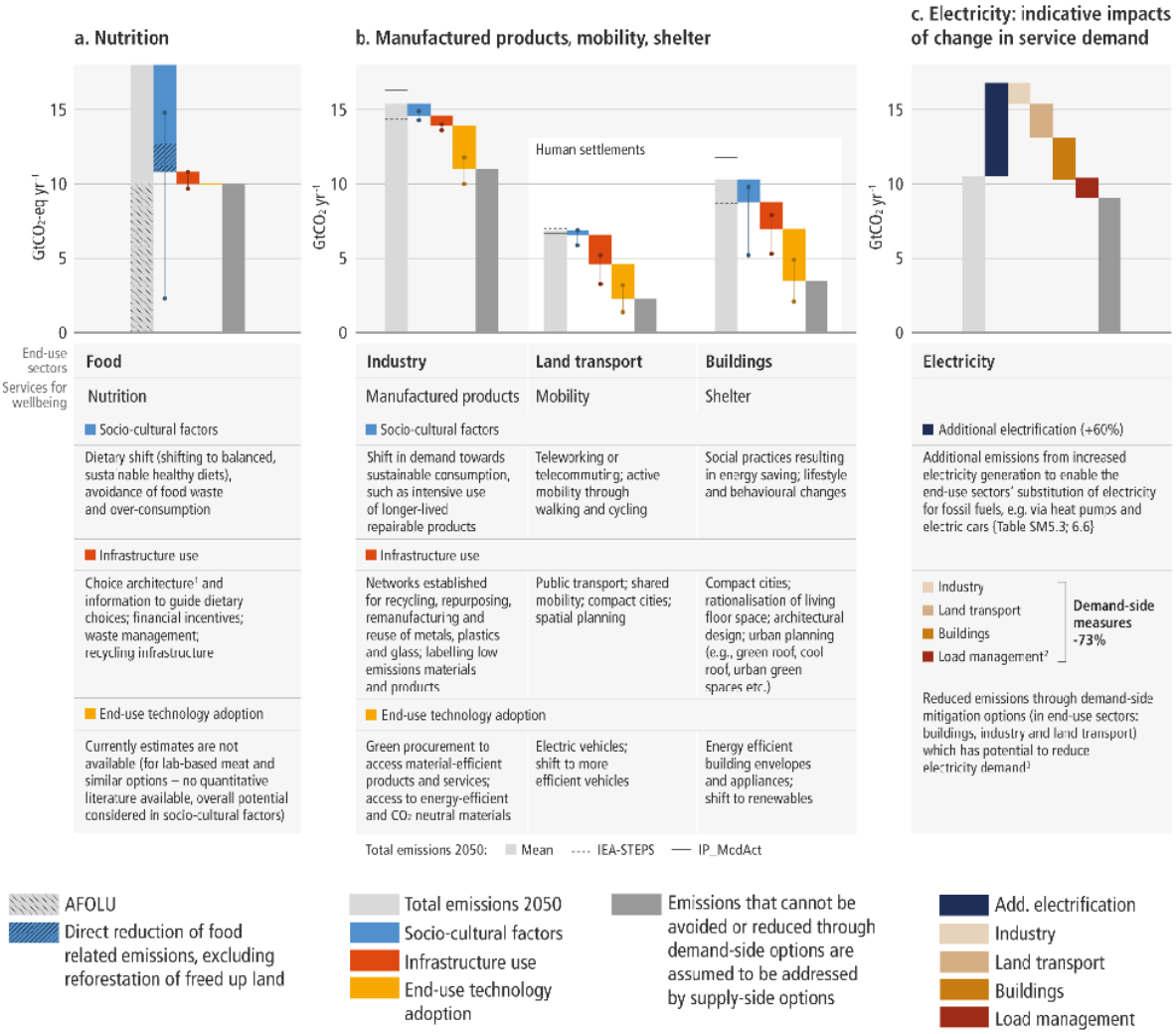
- cutting back on waste
- shifting to plant-based diets

, followed by land transport (6.5$GtCO_2e$). Reductions in transport emissions could involve:

- avoiding travel
- changing from car to public transport
- cutting back on flying.

The report warns however that switching to battery-electric or fuel cell cars could increase emissions.

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




[1] The presentation of choices to consumers, and the impact of that presentation on consumer decision-making.

[2] Load management refers to demand-side flexibility that cuts across all sectors and can be achieved through incentive design like time of use pricing/monitoring by artificial intelligence, diversification of storage facilities, etc.

[3] The impact of demand-side mitigation on electricity sector emissions depends on the baseline carbon intensity of electricity supply, which is scenario dependent.

The report is cautious about how individual behaviour can have an impact:
"Individual behavioural change is insufficient for climate change mitigation unless embedded in structural and cultural change."
and so far it has had little impact.

It is supportive of "nudges," based on how choices are presented to people, that can shape their energy-related decisions: it can increase food waste reduction, use of geothermal district heating, and supports green energy and climate emissions labelling.

## 6. Changing how food is produced and what people choose to eat

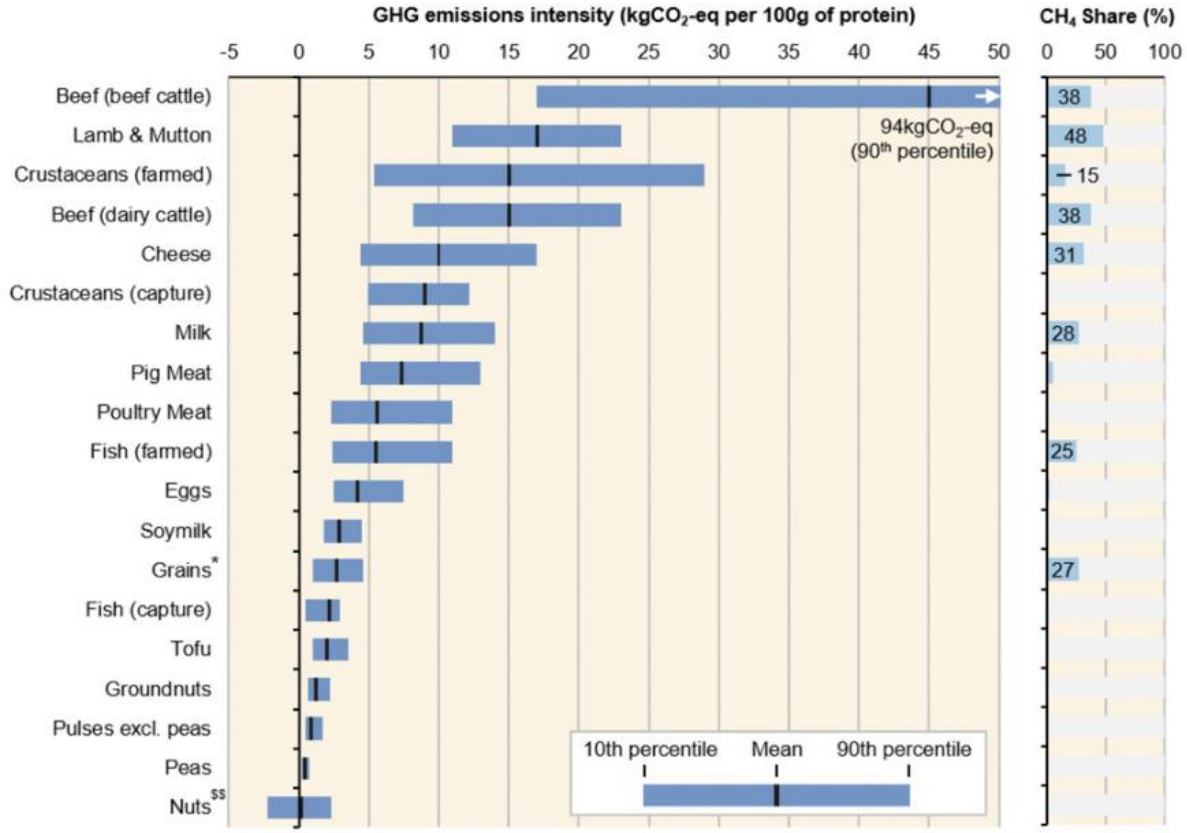
The report says that "food systems" are connected with 42% of global greenhouse emissions and they continue to grow steadily. Greenhouse gas emissions rise with the growth of consumption of meat, dairy and processed food. It would be possible to introduce sustainable food systems

that would enable healthy diets for everybody, but there would need to be good coordination to achieve improved agricultural practices, better consumer choices, and reduction of food waste by producers, distributors, retailers and consumers.

The report suggests:

- moving to a more sustainable diet (31% reduction)
- reduction in meat consumption from ruminants such as sheep and cows especially from beef herds

It gives a chart (figure 12.6) that looks at levels of GHG emissions per 100g of protein supplied. On average 100g of protein from a beef herd cow is linked to 18 times more GHG than fish or tofu and 100s of times more than peas or nuts.




A move to a diet of plant-based protein would not only reduce emissions "substantially", but would also cut land use, leakage of nutrients, and result in a healthier diet with less "added sugars, salt and saturated fats."

"Emerging technologies," such as cultured meat and cultivation systems that require no soil could reduce emissions.

Food waste reduction could cut food emissions by 12%.

Food emissions are not directly related to income levels. Individuals and groups with high food-related emissions are well-distributed across the world. The report suggest a number of initiatives:

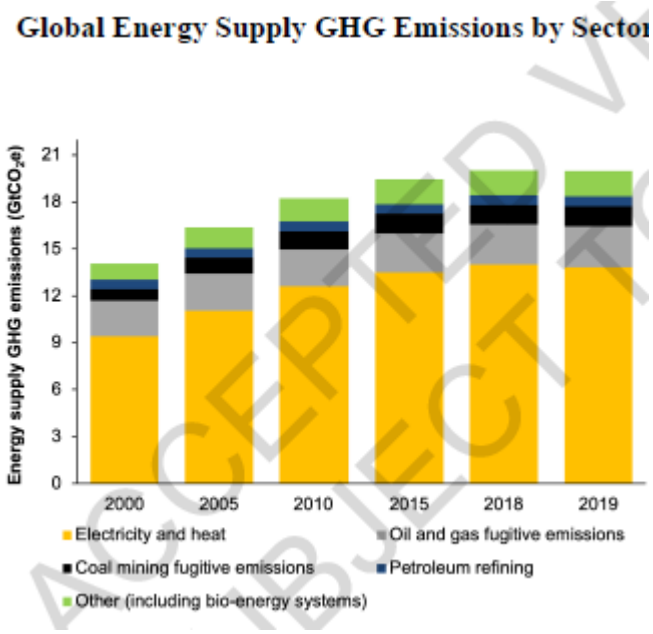
- "novel narratives" that promote plant-based diets

- Marketing regulations
- Procurement policies
- Dietary guidelines
- Labelling
- Other "nudges"

## 7. Changes needed in global energy systems

Energy systems accounted for about two-thirds of global GHGs resulting from human activity in 2019.

" Warming cannot be limited to 2ºC or 1.5 ºC without rapid and deep reductions in energy system $CO_2$ and GHG reductions."




About 36% of this is linked to electricity production and about 69% of the total energy supply emissions are from electricity and heat production. These emissions should be eliminated, especially since electricity will have to meet a majority of our energy needs. About 18% of energy system emissions are linked to leakage.

The cost of low-carbon electricity is reducing. In many places solar power and onshore wind power are cheaper than fossil-fuel power. Change is likely to be rapid. This may be slowed down, however, because of high levels of investment in fossil-fuel production facilities with "long lifetimes." However the report says "decommissioning and reduced utilisation of existing fossil fuel installations in the power sector as well as cancellation of new installations are required" to align future $CO_2$ emissions from the power sector and reduce emissions quickly enough to prevent global heating of more than 1.5 or 2ºC. Use of coal, gas and oil will have to be substantially reduced, especially after 2050.

The report says:

- There are "absolute limits" to the contribution of biomass
- Nuclear has a role but there is a need to improve reactor designs and reduce costs
- Nuclear and carbon capture are developing more slowly than wind, solar, and batteries

- "As a general rule, and across all sectors, it is more efficient to use electricity directly and avoid the progressively larger conversion losses from producing hydrogen."
- Integration of variable renewable energy (inc wind and solar) will require good electricity system management
- Wind power repays its carbon footprint in less than a year
- Global heating will reduce the efficiency of wind and solar power less than it will hydropower, bioenergy, fossil fuel or nuclear.

# 8. Land: emissions and potential for absorbing GHGs

Emissions are highest in Latin America and the Caribbean (58% of total emissions) compared with 7% in Europe and North America. Deforestation is the main cause.

Deforestation is reduced by law enforcement, designation of protected areas, payment for ecosystems, and the presence of indigenous peoples. High agriculture prices, proximity to agriculture, urban areas and roads lead to more deforestation.

Terrestrial ecosystems absorb about a third of human-caused $CO_2$ emissions. Land could absorb increasing amounts of $CO_2$ at relatively low cost by (in order of significance):

1. Protecting and restoring forests, peatlands, coastal wetlands, savannahs and grasslands
2. Agricultural soil carbon management, improved livestock rearing
3. Changes in demand caused by a shift to plant-based diets and reduction of food waste.

These methods are already available in contrast to other ways of capturing carbon. The report says "The use of bioenergy can lead to either increased or reduced emissions, depending on the scale of deployment, conversion technology, fuel displaced, and how, and where, the biomass is produced." The need to develop economic processes might reduce the full potential.

The report warns that "poorly planned" biomass production and tree planting could be counter-productive, but well-planned interventions could have major potential. There are many barriers such as lack of finance and good governance and progress is slow.

# 9. Removing $CO_2$

The report says that $CO_2$ removal is unavoidable to compensate for problems of emissions reduction in, for example, aviation, agriculture or some industrial processes. Ultimately it could enable reversal of greenhouse heating. It warns, however, that the potential is often overstated to counterbalance insufficient wind and solar investment, and reluctance to develop demand-side options.

$CO_2$ removal methods include:

- Afforestation, reforestation, better forest management
- Biochar
- Bioenergy and Carbon Capture and Storage (BECCS)
- Direct Air Carbon Capture and Storage ((DACCS)
- Enhanced weathering
- Peatland and coastal wetland restoration
- Blue carbon management
- Ocean alkalinity management

- Ocean fertilisation

There has been much "fervent debate" on relying on BECCS to reduce emissions and "many recent studies explore mitigation pathways with limited BECCS deployment." There are many barriers to the widespread deployment of many $CO_2$ removal methods.

# 10. Solar Geoengineering

This is a way of tackling global heating by reflecting sunlight away from the Earth. Methods include:

- Reducing heat-trapping cloud cover
- Giant sunshades in orbit
- Pumping aerosols in the stratosphere

The report says that research papers show "high agreement" that solar geoengineering can only be a supplement to emissions reduction methods, would require maintenance, and could be counter-productive.

# 11. Cutting emissions in cities and buildings

In 2020 total urban emissions were about 70% of global emissions and increasing. A city-dweller in 2015 in a developed region caused seven times the emissions of somebody in the lowest emitting region. However the concentration of people in a small area is an opportunity to reduce emissions through systematic transition of infrastructure and spatial arrangements.

- Established cities can reduce emissions by replacing or retrofitting building stock, and switch to clean energy.
- New and emerging cities can create "compact, co-located and walkable urban areas with mixed land use and transit-oriented design, that also preserve existing green and blue assets"
- Rapidly expanding cities can move to low-carbon technologies and adopt planning standards that "co-locate[s] jobs and housing to achieve compact urban form."

Cities can reduce GHG emissions by about 24% by 2050 if they become more compact and resource efficient if they

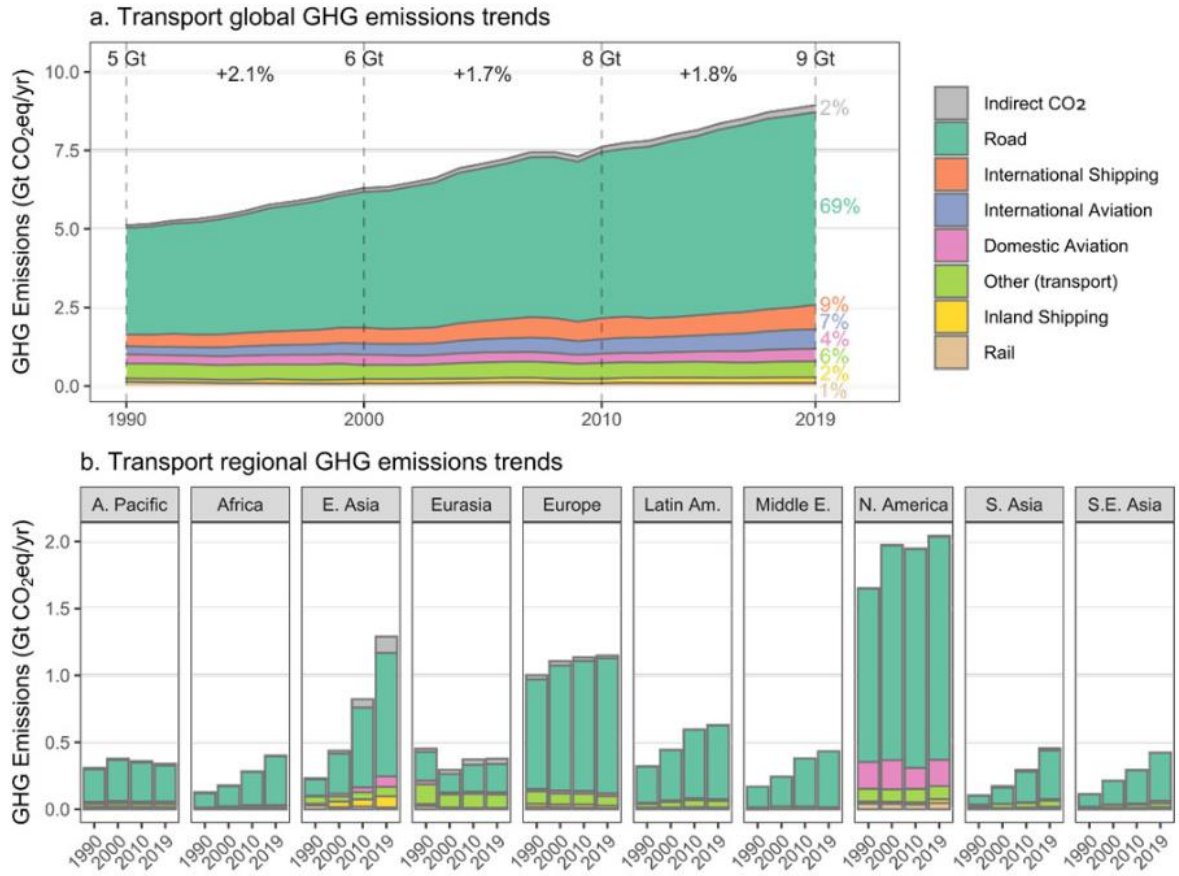
- Reduce spaces between houses and working locations
- Reduce private vehicle use and encourage low-emission public transport use and walking
- Promote urban green infrastructure and energy efficiency in buildings
- Develop capacity to tackle global heating through better access to technology, better local governance, engaging with civil society, and better budgetary mechanisms
- Reduce the carbon footprint of buildings and aim for zero-carbon buildings, through energy efficiency in both construction (lightweighting) and use
- Maximise use of daylight, insulation, heat pumps; and focus on electricity as a power source (because it is more efficient than hydrogen).

# 12. Cutting transport emissions

The report says that "meeting climate mitigation goals would require transformative changes in the transport sector." It was the fourth largest source of emissions globally, but within Hampshire it is the source of over half the emissions. Emissions have grown more rapidly

globally than in other sectors. Emissions are far higher in N America, South East Asia and Europe than elsewhere.

Without mitigation transport emissions could grow 65% worldwide by 2050, but mitigation could reduce transport emissions by a similar amount and contribute to limiting global heating to 1.5ºC. Following the transport emissions reduction during Covid-19 there is now "growing awareness" of the need for "systematic infrastructure changes that enable behavioural modifications and reductions in demand for transport services that can in turn reduce energy demand."




The report lists a range of ways to reduce transport emissions (p 1692):

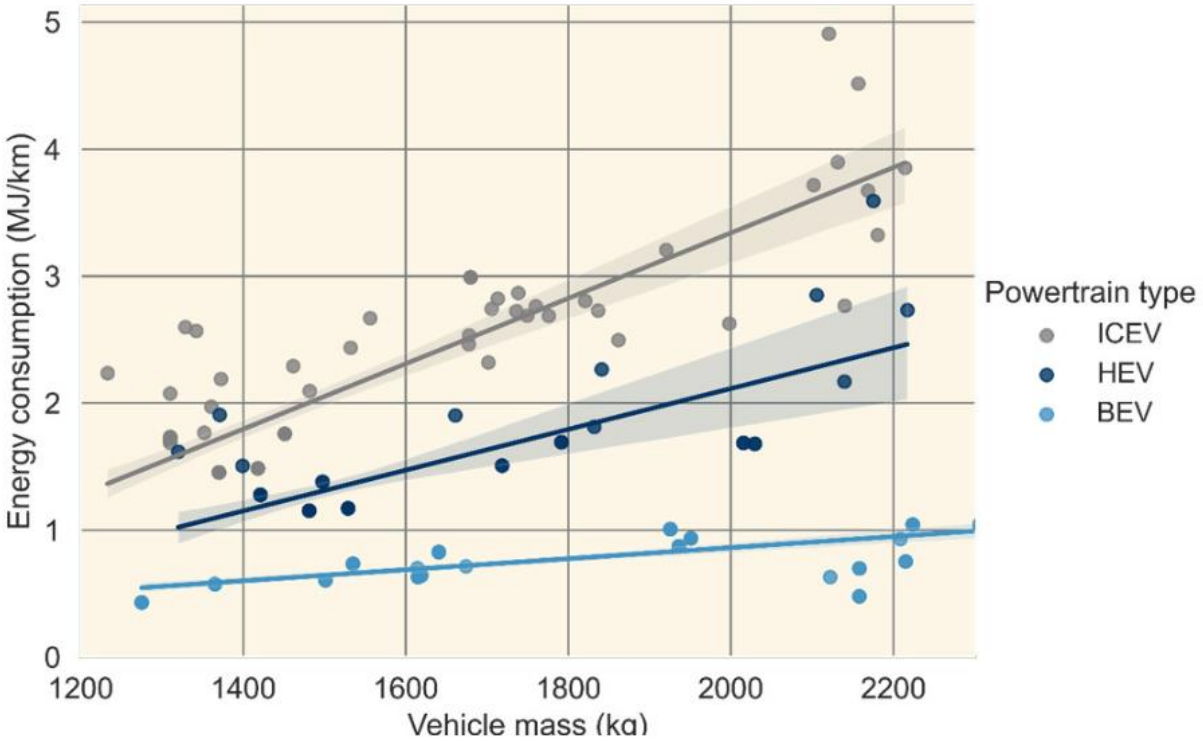
- Denser, more compact cities with mixed land use
- Developing public transport systems and supporting walking and cycling
- Changes in economic structures: economic crises, pandemics
- An increase in remote working, reducing commuting
- Combining functions into fewer devices could reduce the volume of consumer goods
- Better logistics planning making more efficient use of transport infrastructure
- Increased e-commerce
- Better smart mobility to enable public transport and active travel to compete more effectively with the car

The report is confident that battery-electric road vehicles have lower full-life GHG emissions if using green electricity than internal combustion engine vehicles and will soon be cheaper to run. Opportunities will increase (e.g. for long-haul goods transport) as batteries are developed. The

report is less sure about hydrogen vehicles using green hydrogen but says that there may be cost reductions and GHG reduction with more research and development on the vehicles themselves and on hydrogen production.

Biofuel production may need further development and investment to maximise its compatibility with low-carbon land-management strategies; also costs are currently often high. There may be more potential for adapting shipping to using biofuels than for adapting aviation where there is less flexibility in the technology.

Currently hydrogen vehicles use over twice the energy used by battery-electric vehicles, and internal combustion engines use almost three-times the amount. Electric vehicles can reduce the amount of energy needed.




Two-wheeled electric vehicles need less power than four-wheeled vehicles and achieve lower life-cycle GHG emissions.

The report suggests the potential of greater use of public transport. "At high occupancy bus and rail transport offer substantial GHG reduction potential per passenger km, even compared with the lowest-emitting private vehicle options. Even at 20% occupancy, bus and rail may still offer emission reductions compared to passenger cars, especially notable when comparing BEVs with low-carbon electricity (the lowest emission option for all technologies) across the three modes…Under most parameter combinations, rail is the most cost-effective option, followed by buses, both of which are an order of magnitude cheaper than [private] passenger vehicles.. Note that costs per passenger km are strongly influenced by occupancy assumptions; at low occupancy (e.g., <20% for buses and <10% for rail), the cost of transit approaches the LCC for passenger cars."

There are problems that still need to be resolved in the decarbonisation of freight land transport. For heavy road freight natural gas based fuels may not lead to carbon reduction and vehicles

with battery-electric vehicles and "decarbonisation of medium and heavy-duty trucks would likely require the use of low-carbon electricity in battery-electric trucks, low-carbon hydrogen or ammonia in fuel-cell trucks, or bio-based fuels (from sources with low upstream emissions and low risk of induced land use change) used in ICE trucks." However, Trains are more energy efficient (per tonne km) than trucks, so expanded use of rail systems (particularly in developing countries where demand for goods could grow exponentially) could provide carbon abatement opportunities."

.

There are major problems with decarbonising air travel. Many ideas are being explored, such as rerouting new fuels and engine redesign, but have not been tested, and offsetting schemes such as CORSIA are in their early stages, and do not apply to many flights. Offsetting schemes do not lead to in-sector emissions reductions.

Perhaps more promising is modal shift from air travel to high-speed rail. In China flights have reduced following the introduction of Wuhan-Guangzhou and Beijing-Shanghai high-speed rail services. Levels of GHG reduction will depend on local circumstances, such as the mix of electricity used.

# 13. Decarbonising Industry

Industry accounts for 34% of global emissions and the sector is "expected to decarbonise slower than other[s]." It will be possible to reduce emissions to net zero, but "challenging."

Technological shifts and new technologies could reduce the greenhouse gas intensity of major materials to net zero to net zero by 2050. Plastic, for example, currently relies over 99% on fossil 'feedstock.' Very low levels of recycling and petrochemical processes that emit considerable fossil fuels. There is a need for transformational change.

A concentration on efficiency in producing materials and circular processes could reduce the need for carbon capture and storage.

For steel production there needs to be more emphasis on:

- Producing steel that lasts longer, designed for reuse and easier recycling
- Using lower carbon fuels such as biomass and hydrogen with carbon capture, or electrolytic iron ore reduction and electric arc furnaces
- Better blast furnaces with liners that enable 90% carbon capture
- Adopting molten oxide electrolysis, or aqueous electrolysis with high temperature electrodes.

Cement production could reduce its emissions by

- Switching to alternative materials for construction
- Restricting concrete to only where it is necessary
- Developing alternative materials, such as a low GHG binder
- Using carbon capture until alternative methods are developed.

Chemicals production can reduce emissions by

- Decarbonising the materials they use and moving to material that produce less GHGs such as hydrogen, ammonia, methanol, carbon monoxide, ethylene, propylene or aromatic chemicals, and accepting that they might cost more

- Using biomass or electricity-based replacements may cost more and may be in short supply.

Industry should embrace circular processes and move away from an "extract-produce-use-discard" model,. for example, chemically recycling plastic. They could make better use of waste and create regional "eco-industrial networks". "Industry has so far largely been sheltered from the impacts of climate policy and carbon pricing due to concerns for competitiveness and carbon leakage"

Energy and climate policies have not so far explored industrial processes. This "partly results from…a lack of high-level political focus, a history of strong industrial lobbying, uncoordinated policy across subsectors and institutions, and the sequential nature of decision-making along supply chains."

# 14. Progress on policies so far

Although policies adopted have avoided several billion tonnes of $CO_2$ emissions each year, they fall short of what is needed, especially on non-$CO_2$ greenhouse gases and industrial emissions.

By 2020 climate laws were in place in 53 nations covering 53% of global emissions.

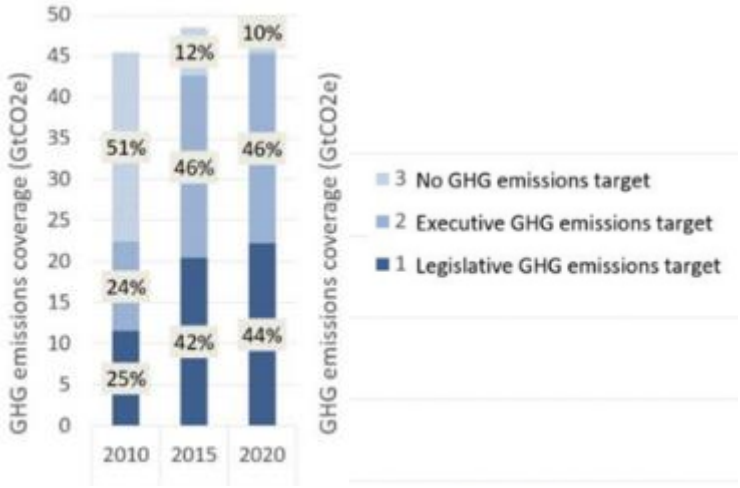



Figure 13.2 (extract)

Targets vary considerably in nature, and more ambitious targets have not necessarily led to greater action. Some countries such as China, UK, and New Zealand have set up institutions to tackle climate change, but some countries lack the capacity.

One of the most widely used and effective mechanisms has been carbon pricing (taxing and emissions trading). The report finds however that "both coverage and price are lower than is needed for deep [emissions] reductions."

The removal of fossil fuel subsidies could cut emissions by up to 10% by 2030, but there is resistance from both industry and consumers.

Feed-in tariffs have been effective in expanding renewable energy production.

The report notes that left-wing and green politicians "tend to adopt more pro-climate policy positions." Tackling climate change tends to be more effective in political systems where there is proportional representation, broader public participation, and less government lobbying. The report is critical of the role played by fossil fuel companies, who it says have been "important agenda-setters in many countries, including the US, the EU, Australia, China, India and Mexico."

The report observes that "more confrontational forms of climate activism have become increasingly common" and that many projects ended up being cancelled as a result.

The report observes that concern about climate change is growing and media coverage is becoming more accurate. It refers to reaction, such as the gilet jaune protests in France and the importance of taking account of affected communities.

## 15. Using the Paris Agreement and developing climate finance

The report says international cooperation is having "positive and measurable results."

The Paris Agreement had allowed countries to set their own targets (Nationally Determined Contributions (NDCs). There is debate about whether this will achieve the kind of transformational change needed. On the one hand there has been increased participation, lower costs for low-carbon technologies, and more support from countries. On the other hand NDCs are not legally binding and targets set are inconsistent. Existing NDCs will leave an emissions gap and would allow global warming of 3ºC by 2100. The report suggests:

> "Ultimately, the overall effectiveness of the Paris Agreement depends on its ability to lead to ratcheting up of collective climate action to meet the long-term global temperature goal… there is some evidence that this is already occurring."

The report would like more international cooperation to finalise rules for finance and "better address sector-specific technical and infrastructure challenges."

There are "transboundary" issues: aviation and shipping targets, and a need for a common approach to solar radiation modification and carbon dioxide removal.

Finance for climate adaptation and mitigation has increased by up to 60% between 2014 and 2020 but still too little money is being invested in renewables and low-carbon transport. Developing nations need between four to eight times more investment up to 2030 than they are currently getting. Fossil fuel financing remains high.

Climate finance needs clearer definition and should be classed as "grant equivalent," like other forms of international aid. Climate risks are understated and this is a barrier to sufficient funding.

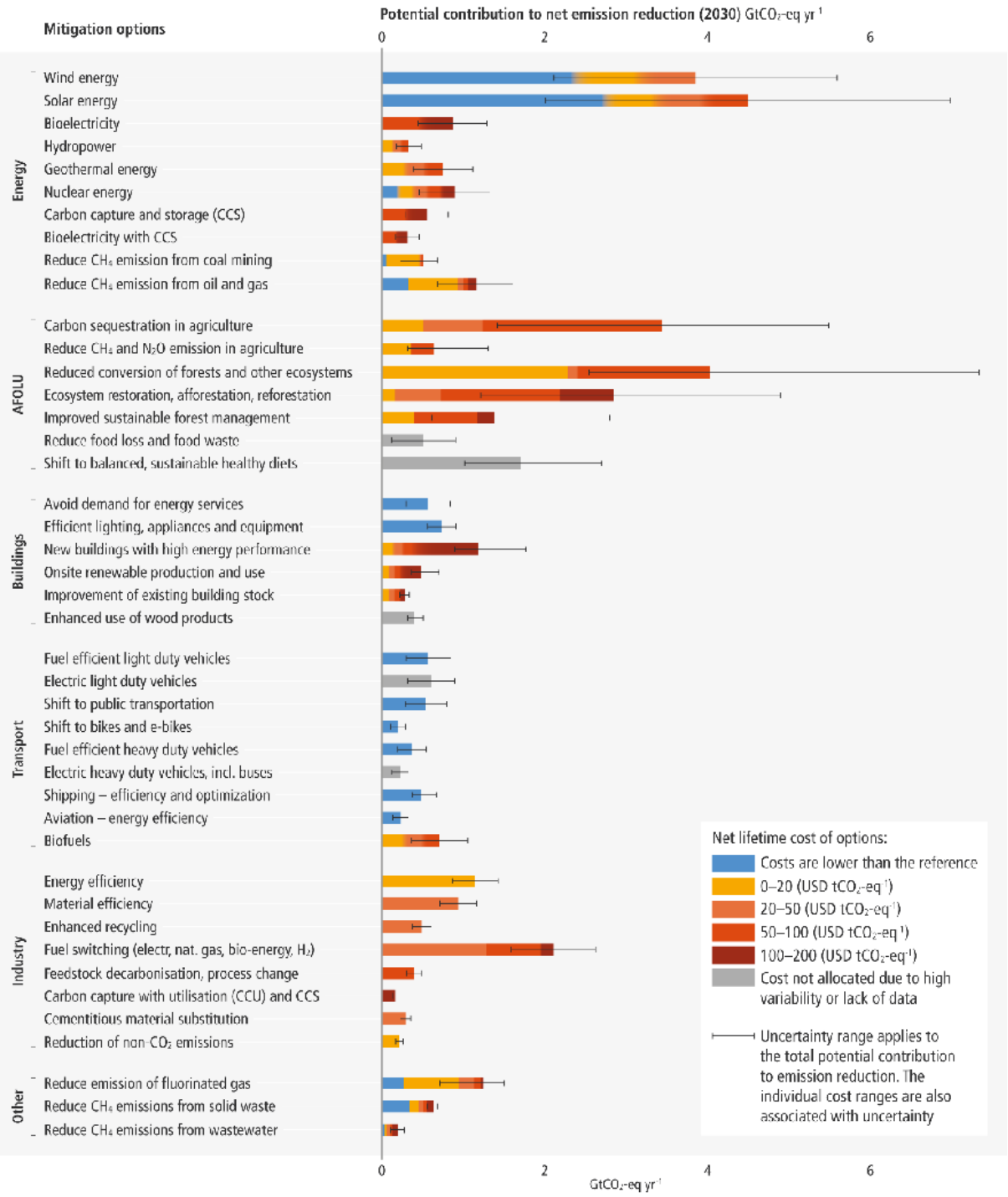
## 16. Paying for and benefitting from emissions cuts

The costs of avoiding global warming are less than the costs of allowing it to happen. There are economic benefits from the improvement in air quality that climate change mitigation brings about. With 2ºC global warming it is estimated that global GDP would be 1.3 to 2.7% lower in 2050 than it would be without warming.

Following the Covid-19 pandemic "a green investment push, would initially boost the economy while also reducing GHG emissions."

The following chart (figure SPM 7) shows the impact (length of line) and cost (colour: blue low, red high) of specific interventions:

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



## 17. Speeding up development of new ideas and technologies

The report looks at recent innovations and how prices have reduced for: photovoltaics, onshore winds, offshore winds, concentrating solar power, batteries for electric vehicles, and how use has grown. It observes that it took photovoltaics 60 years to achieve widespread adoption and this would be "too slow for addressing climate change if a technology is now still at the lab scale." There is a need for a strategy to take innovation from research to widespread use within 15 years.

## 18. Supporting sustainable development

The UN has 17 sustainable development goals to be achieved by 2030, covering poverty, energy access, hunger, inequality and biodiversity among other things. One of the goals is about climate change and many others are linked to climate action. The report warns, though, that some policies may need to be carefully designed to ensure there is no conflict between policies on climate change and sustainable development.

Sustainable development goals will vary depending on a country's resources, history or political conditions. There are few countries that have linked their sustainable development goals and their nationally determined contributions towards tackling climate change (NDCs). The report says that because lower income countries are affected by climate change more than relatively affluent countries there is a "strong link" between tackling climate change and sustainable development.

The report believes that "eradicating extreme poverty, energy poverty and providing decent living standards…can be achieved without significant global emissions growth." Universal access to energy can be achieved through a mix of increased energy efficiency and rapid social transformation.

Stringent mitigation policies, heavily reliant on land can have a negative effect on food security by driving up land and food prices. However, climate mitigation can reduce food insecurity by preventing loss of crop productivity caused by warming.

Improved air quality alone may bring about benefits of greater value than the whole cost of achieving climate targets. Reducing emissions to keep global warming to 1.5ºC could prevent 150 million premature deaths between now and 2100, primarily because of the reduction in particulate matter.

A "just transition" will reduce climate risks and address sustainable development priorities at the same time. The report calls for climate finance to focus on global inequality, national policies, and support for local communities.

*Phil Gagg*
*WinACC trustee*
*16 May 2022*