CLIMATE CHANGE 101.

An introductory guide

Important information to help engineers understand climate change and take action.

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engineering new zealand
te ao rangahau

ENGINEERING CLIMATE ACTION

What you need to know.

WHAT IS CLIMATE CHANGE?

Anthropogenic (human-induced) climate change refers to the long-term shifts in temperature and weather patterns caused by human activity. Our climate has natural variations in the short term (El Niño Southern Oscillation (ENSO)) and long term (Pacific Decadal Oscillation). However, since the late 1700s the main driver of climate change has been the burning of fossil fuels, such as coal, oil, and gas.

How did this happen?
Our atmosphere (the layer of gases, water vapour and aerosols that surrounds our planet) protects life on Earth from the harmful radiation of the sun and space. Greenhouse gases (GHGs) in the atmosphere allow the incoming energy from the sun to penetrate the atmosphere. This energy transforms into heat at Earth's surface and radiates as longwave radiation back into the atmosphere. Atmospheric gases absorb some of the outgoing heat energy and reflect it back to Earth – and this, in essence, is the greenhouse effect.

SINCE THE INDUSTRIAL REVOLUTION WE HAVE EMITTED INCREASING AMOUNTS OF ANTHROPOGENIC GHGS INTO THE ATMOSPHERE FROM ACTIVITIES SUCH AS THE BURNING OF FOSSIL FUELS FOR TRANSPORT AND INDUSTRIAL PROCESSES, AS WELL AS DEFORESTATION AND LAND-USE CHANGE FOR AGRICULTURE.

Since the industrial revolution we have emitted increasing amounts of anthropogenic GHGs into the atmosphere from activities such as the burning of fossil fuels for transport and industrial processes, as well as deforestation and land-use change for agriculture. This has resulted in a rise in the amount of radiation absorbed in the atmosphere and reflected back to Earth's surface. This has caused the planet to warm (hence the term 'global warming').

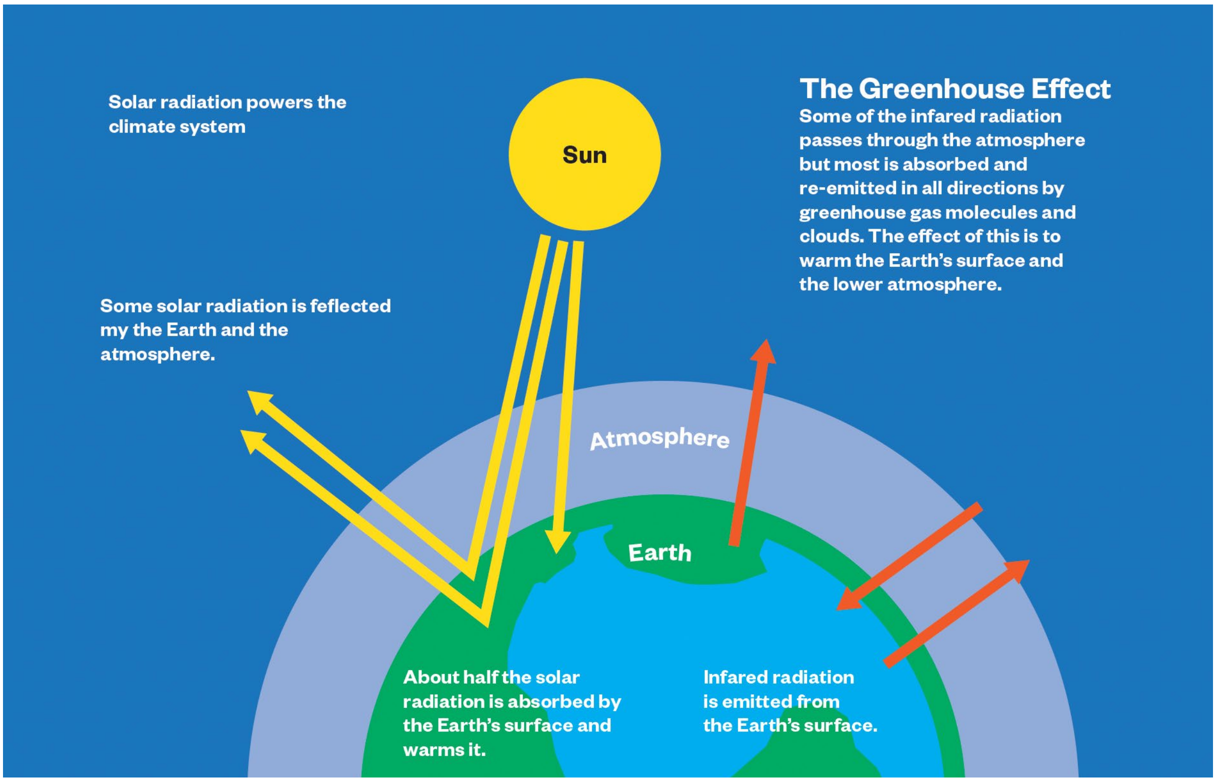

Figure 1: The greenhouse effect (Simplified)[1]

[1] From Le Treut et al., 2007, as cited by NIWA. (n.d.) The greenhouse effect. https://niwa.co.nz/our-science/climate/information-and-resources/clivar/greenhouse

Greenhouse gases

GHGs include naturally occurring molecules (carbon dioxide (CO_2), methane (CH_4), water vapour (H_2O) and nitrous oxide (N_2O)), as well as manmade molecules (sulphur hexafluoride (SF_6) and chlorofluorocarbons (CFCs)). Human activities have significantly increased the quantity of both types of GHGs in the atmosphere.

Different GHGs have different effects as they remain in the atmosphere for different durations and have different properties. Carbon emissions (of which CO_2 is the greatest contributor) remain in the atmosphere for centuries. Biogenic methane, from agriculture and waste, breaks down within decades but absorbs more longwave radiation while in the atmosphere, and therefore has a greater short-term impact on warming than does carbon.

When referred to in measurements, budgets, and targets, total amounts of GHGs are often put in terms of tonnes of carbon dioxide equivalent (tCO_2e). tCO_2e is a widely used GHG equivalence metric which converts different GHGs into a common scale, so they are expressed as though they have the same effect as a unit of CO_2.

Sequestration

Carbon sinks absorb CO_2, reducing (sequestering) the overall concentration in the atmosphere. Plants (both on land and in the ocean) are the greatest CO_2 sinks. Land-use changes, as well as damage to natural environments such as wetlands and forests, have reduced the amount of carbon sinks on Earth. Ocean acidification and warming have also impacted the ability of the ocean to act as a sink. Currently oceans are estimated to absorb between 30 to 40 percent of anthropogenic CO_2.

Breakdown of emissions

In 2019 the Ministry for Environment provided a comprehensive breakdown of emissions by sector and sub-category, summarised in Figure 2 below. The inner chart shows overall sectors; the outer ring extends to subcategories.

Impacts

Aotearoa is already experiencing the impacts of anthropogenic climate change. An example of this is the average rise in air temperature by around 1.1˚C[3] and sea level rise of as much as 20cm over the 20th century through to present.[4]

The predicted impacts of anthropogenic climate change are varied. **In Aotearoa this means**:

> Temperature rise – an increase in average surface temperature, more frequent/intense hot days (above 25˚C) and heatwaves. Cold extremes and snow cover and depth will continue to decrease.
>
> Changes to precipitation – increases in areas that already have high amounts of rainfall (such as the West Coast of the South Island) and decreases in dry areas that already have low amounts of rainfall (such as Northland, Hawkes Bay, Gisborne, the Wairarapa, and the South Island high country). Generally, this means wetter winters and drier springs and summers.
>
> Increased drought risk – longer dry spells and higher temperatures.
>
> Extreme events – precipitation and temperature changes mean an increase in the frequency and severity of extreme weather events (cyclones, storms, floods, and wildfires).

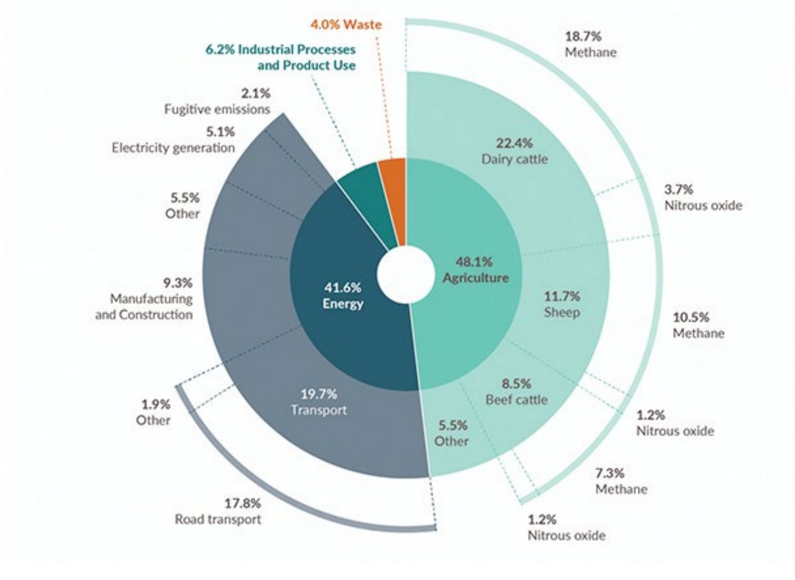

Figure 2: Gross greenhouse gas emissions in 2019 by sector, sub-category, and gas type.[2]

[2] Ministry for the Environment. (2021, April 1). Key findings of the 1990-2019 Inventory. https://environment.govt.nz/publications/new-zealands-greenhouse-gas-inventory-1990-2019-snapshot/key-findings-of-the-2021-inventory/

[3] IPCC, 2021: Regional fact sheet – Australasia. In: Climate Change 2021: The Physical Science Basis.

[4] NIWA. (n.d.) Sea levels and sea-level rise. https://niwa.co.nz/natural-hazards/hazards/sea-levels-and-sea-level-rise#c3

KEY CLIMATE CONCEPTS

Anthropogenic climate change

Human-induced climate change is demonstrated in Figure 3 below. This shows the significant increase in temperature since the industrial revolution, compared to very likely temperatures of the last 2000 years, and the very likely estimated temperature range the last 100,000 years.

Mitigation

The process of reducing the severity of climate change by reducing emissions.

Mitigation looks at reducing GHG emissions to limit the amount of additional warming (compared to pre-industrial times) and minimise and avoid the increasingly severe and widespread effects of climate change.

Mitigating climate change is not the same as avoiding or alleviating climate change. Avoiding or alleviating climate change is impossible because it is already occurring. Future warming is inevitable due to GHGs already emitted. However, negative emission technologies, like carbon capture and storage, could 'undo' some climate change in the future by taking carbon dioxide out of the atmosphere now.

Many countries and organisations have emissions reduction goals and targets. Common terms when talking about mitigation goals include: carbon zero, carbon neutral, carbon negative, carbon or climate positive, low emissions, low carbon, zero emissions, net zero and net zero emissions. In Aotearoa, we often use the term 'net zero', which is broadly the same as 'carbon neutral'. 'Net zero' is where some emissions are still generated but are offset to reach zero net total emissions.

Transition

The process of transitioning to a low emissions future.

Transition engineering

'Transition engineering' is an emerging discipline. It applies the same concepts that guide the practice of safety engineering to the climate transition. **These principles are as follows:**

> prevent what is preventable
>
> be honest with employers and the public about problems and possible solutions
>
> ensure professional engineering work to mitigate and adapt to climate change is based on knowledge and experience
>
> follow standards to protect life and health, now and in the future, by right of responsibility.

Just transition

'Just transition' is about ensuring that the processes of mitigation, adaption, and transitioning our society to net zero are equitable, inclusive, and fair. This requires working in partnership across society to ensure that the benefits and costs of climate initiatives are clear and shared in a way that is just. The idea of a just transition applies to the transitioning of the workforce away from fossil fuel intensive industries, as well as understanding the broader social and cultural implications of climate change solutions.

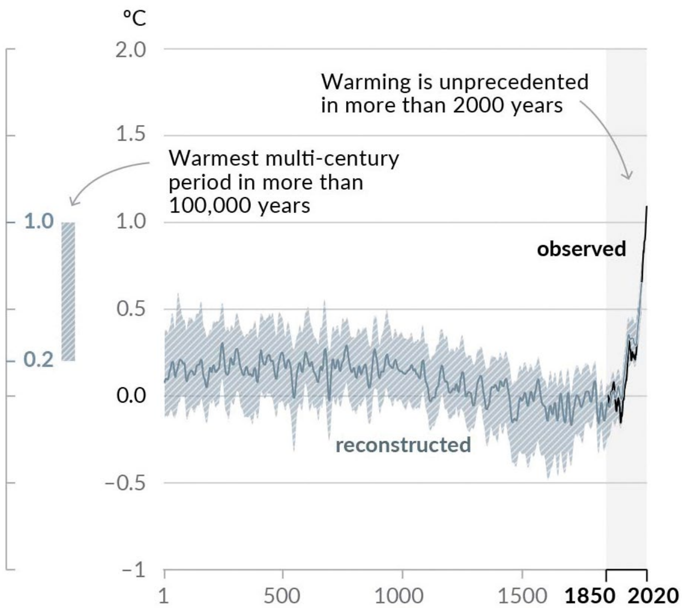

Figure 3: History of global temperature change and causes of recent warming.[5]

[5] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis, p. 6.

Adaptation

The act/process of changing to manage the actual and expected effects of climate change.

Adaptation enables increased resilience to the physical, social, economic, and cultural impacts of climate change. The aim of adaptation is to minimise harm and costs (including non-financial costs such as biodiversity loss) and maximise opportunities and benefits. There are a range of adaptation measures. Hard adaptation measures tend to be expensive, complex, and inflexible (eg reinforced buildings, dykes and seawalls). Soft adaptation measures tend to be simpler, modular, flexible and more community focused and controlled (eg early warning systems, skill capacity development and education, planting mangroves). Adaptation measures can be applied to natural and human-made systems, and include natural and human-made solutions.

Maladaptation is when adaptation (and/or mitigation) measures have unintended adverse effects, increasing the vulnerability of sectors, systems, or communities. Maladaptation undermines the capacity and opportunities for present and future adaptation and highlights the importance of analysing options. Maladaptation can negatively impact a specific geographic or social area (spatial maladaptation) or it can have negative impacts over time, including into the future (temporal adaptation). Maladaptive measures also have implications for climate change mitigation in that they can increase GHG emissions.

Uncertainty

Climate change is a complex phenomenon. Scientific evidence for anthropogenic climate change is unequivocal.[6] Yet uncertainties remain about the extent of its effects. An editorial in Nature Climate Change put it clearly:

“The broad-scale impacts and mechanisms of physical climate change are scientifically well-understood, but specific estimates of these impacts are associated with uncertainty that is challenging to communicate.”[7]

Risks and impacts

Climate change poses risks to many things we value. However, outcomes are uncertain because future risks and impacts depend on the mitigation and adaption measures we undertake today and into the future. For these reasons, risks and impacts are often assessed. Risks result from the interactions between vulnerability, exposure, and hazard. Risk is often represented as the probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

Climate change risks can be assessed by considering:

> vulnerability – predisposition or propensity of people, species or ecosystems, environmental functions, services, and resources, livelihoods, infrastructure, or assets to be adversely affected by climate change. It encompasses sensitivity and susceptibility to harm as well as lack of adaptive capacity
>
> exposure – presence of people, species or ecosystems, environmental functions, services, and resources, livelihoods, infrastructure or assets in locations and contexts that may be adversely affected by climate change
>
> hazards – climate-related physical events, trends or physical impacts that cause harm such as death, injury, or other health impacts, and/or damage to or loss of livelihoods, infrastructure, service provision, ecosystems, environmental resources, and property.

Vulnerability, exposure, and hazards are driven by changes in the climate system, as well as socioeconomic processes (including adaptation and mitigation).

Resilience

Resilience is the capacity of systems (built, social, economic, and environmental) to cope with hazards by responding or reorganising in ways that maintain the essential function, identity, and structure of the system. This is a key concept for engineers to incorporate into design and construction, to ensure the built environment can withstand the effects of climate change.

[6] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis.

[7] Scientific uncertainty, p. 797.

CLIMATE CHANGE LEGISLATION

Climate Change Response (Zero Carbon) Amendment Act 2019

The **Climate Change Response (Zero Carbon) Amendment Act 2019** provides the framework by which the government must reduce Aotearoa's GHG emissions to meet our international obligations under the 2015 Paris Agreement and prepare for, and adapt to the effects of climate change. **The Act sets two domestic GHG emissions reduction targets. To:**

- reduce net emissions of all greenhouse gases (except biogenic methane) to zero by 2050, and
- reduce emissions of biogenic methane to 24–47 percent below 2017 levels by 2050, including to 10 percent below 2017 levels by 2030.

Other key features of the Act are that it establishes a Climate Change Commission. The Commission must develop and present a National Climate Change Risk Assessment and National Adaptation Plan every six years.

New Zealand Emissions Trading Scheme

The New Zealand Emissions Trading Scheme (NZ ETS) was established in 2008 under the Climate Change Response (Emissions Trading) Amendment Act 2008. For many years it has been the government's main policy tool for reducing GHG emissions. Under the NZ ETS businesses must measure, report, and pay for their GHG emissions. To pay for GHG emissions, business can reduce their emissions or purchase emission units from other businesses.

THE CLIMATE CHANGE RESPONSE (ZERO CARBON) AMENDMENT ACT 2019 PROVIDES THE FRAMEWORK BY WHICH THE GOVERNMENT MUST REDUCE AOTEAROA'S GHG EMISSIONS TO MEET OUR INTERNATIONAL OBLIGATIONS UNDER THE 2015 PARIS AGREEMENT AND PREPARE FOR, AND ADAPT TO THE EFFECTS OF CLIMATE CHANGE.

Emissions Reduction Plan

Aotearoa's first Emissions Reduction Plan (ERP) is currently being developed and will outline policies and strategies for meeting our first emissions budget (2022-2025). This work will significantly influence climate action over the next 15 years.

The ERP covers the following sectors:

- Transport
- Energy
- Waste
- Building and construction
- Agriculture and forestry

The final plan will be published in May 2022.

Resource Management Act 1991

Currently, the **Resource Management Act 1991** governs how people interact with Aotearoa's natural resources while developing our built environment. Aotearoa's resource management system is currently under review. Three Acts – a Climate Adaptation Act, the Natural and Built Environments Act and a Strategic Planning Act – will replace the current Resource Management Act 1991. For more information on the review visit the Ministry for the Environment's website.

Further information.

USEFUL LINKS

Aotearoa New Zealand

NIWA, the National Institute of Water and Atmospheric Research, is a Crown Research Institute that was established in 1992. NIWA conducts and disseminates research across freshwater, climate and ocean across New Zealand and the wider Pacific region.

The Climate Change Commission provides the government with independent advice on mitigating and adapting to climate change. It also monitors and reviews the government's progress towards targets and goals. They also run **online talks** that are recorded.

The Ministry for the Environment is the 'lead' ministry for Aotearoa's climate change response. They also publish **resources** on the science, evidence, projections and impacts of climate change and how our activities contribute to climate change.

The Royal Society of New Zealand Te Apārangi has a variety of resources on what climate change means for Aotearoa New Zealand.

International

The Intergovernmental Panel on Climate Change, was formed in 1988 through the United Nations Environment Programme and the World Meteorological Organization. The IPCC regularly assess and summaries up to date scientific knowledge on climate change covering the basis, impacts, adaptation, and mitigation. Their work programme is set by governments, with scientists producing reports. IPCC reports influence international and national policy and are referenced by non-government organisations and scientists. The IPCC is considered the go-to for scientific evidence on climate change.

The World Federation of Engineering Organisations (WFEO) has published a Code of Practice for Sustainable Development and Environmental Stewardship, and is actively involved in the United Nations Sustainable Development Goals, including SDG 13: Climate Action.

The Harvard Business School's initiative, **Confronting Climate Change**, also summaries the challenges well.

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