2019
Version

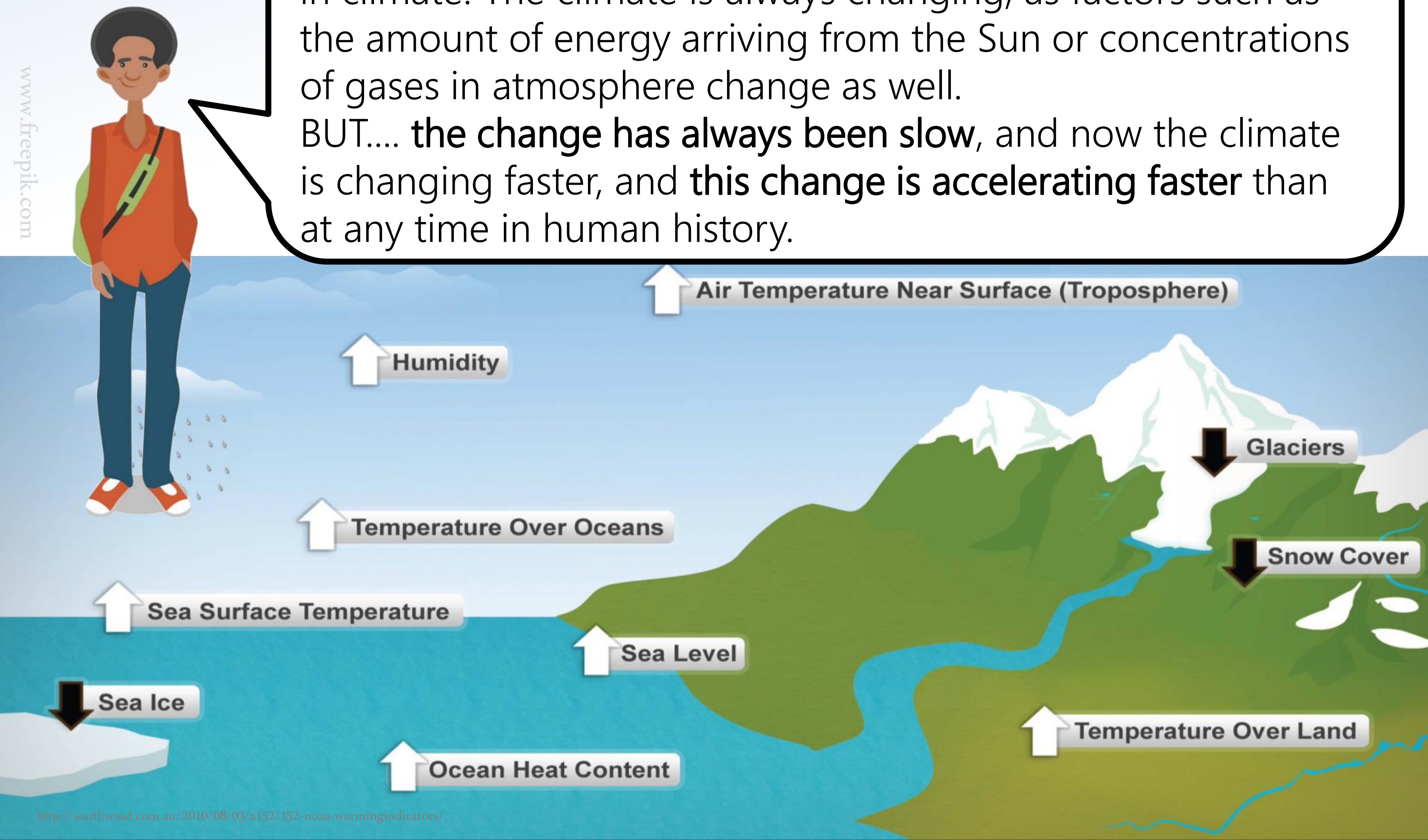
Climate Change
Junior Science

https://commons.wikimedia.org/wiki/File:Greenland_Ice_Sheet_(3970865344).jpg

GZ Science Resources

What is Climate Change?

Climate change is a long-term change (that we can measure) in climate. The climate is always changing, as factors such as the amount of energy arriving from the Sun or concentrations of gases in atmosphere change as well.
BUT…. **the change has always been slow**, and now the climate is changing faster, and **this change is accelerating faster** than at any time in human history.



http://southwind.com.au/2010/08/03/a152/152-noaa-warmingindicators/

Why is the Climate Changing?

This recent climate change is occurring due to **human-caused activities** (called anthropogenic activities). Past and present human industry, including the burning (combustion) of **fossil fuels**, transportation, and agriculture, have increased the concentration of **greenhouse gases** in the atmosphere.

https://www.climatechangenunavut.ca/en/climate-change

Wait!!! Human-caused activities, fossil fuels, greenhouse gases??? What do all those words mean? And how can we be actually sure we are causing climate change?

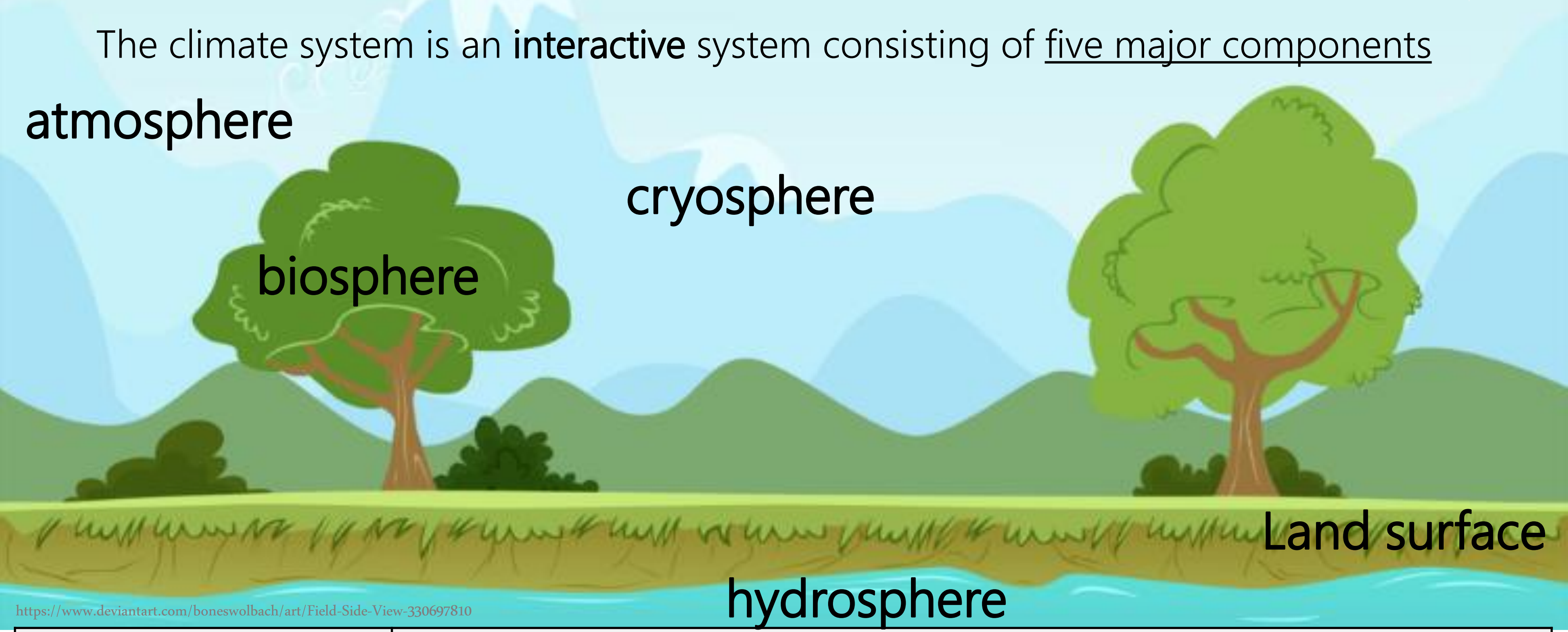
Are Humans responsible for climate change?

Scientists have been able to collect evidence, and use models, to tell the difference between natural sources and human sources of climate change. Evidence also shows that human made CO_2 is the main cause of climate change.

Lets start at the beginning, we need to find out what a *climate* is, where the carbon comes from, what greenhouse gases are, and how they cause the climate to change.

Components of Climate

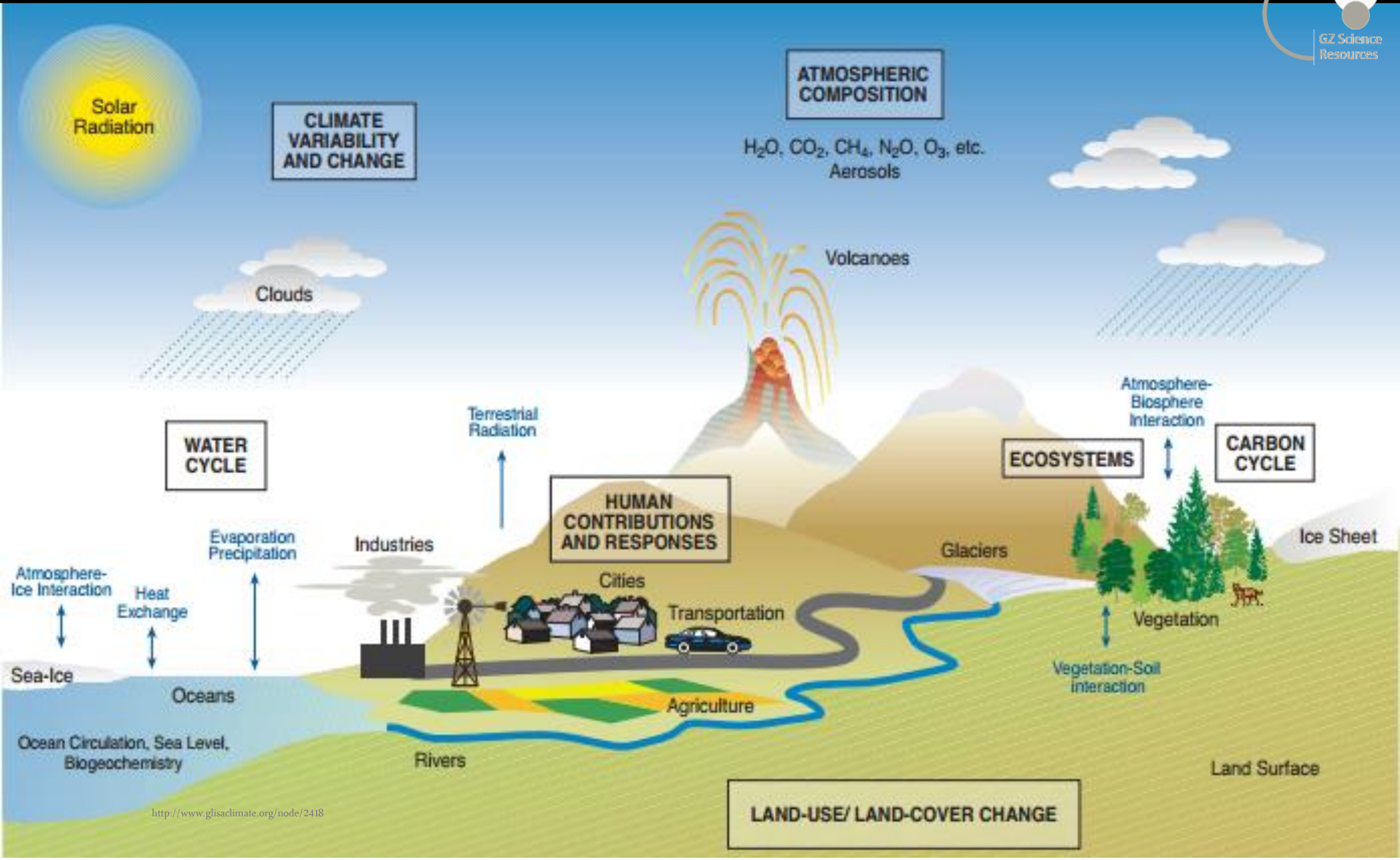
The climate system is an **interactive** system consisting of five major components



https://www.deviantart.com/boneswolbach/art/Field-Side-View-330697810

Component	Comprised of:
Atmosphere	N_2, O_2, Ar, H_2O, CO_2, CH_4, N_2O, O_3, aerosols
hydrosphere	Rivers, lakes, oceans
cryosphere	Sea ice, ice sheets, glaciers, and permafrost
Land surface	The top layer of the Earth, exposed to the atmosphere
biosphere	All living organisms found below, above and on the land

Components of Climate



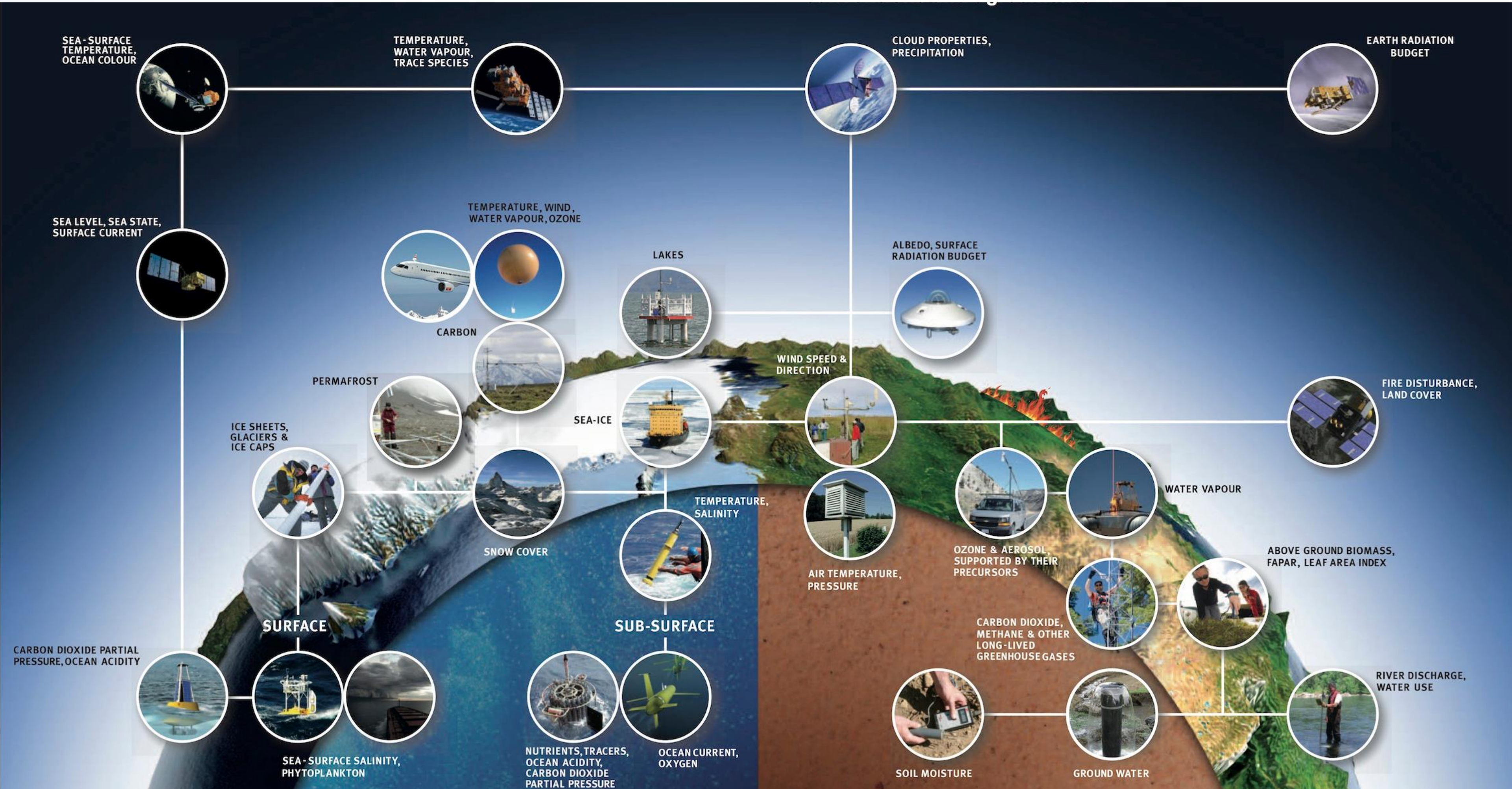
http://www.glisaclimate.org/node/2418

The components are influenced by many variables, the most important of which is the Sun. Any change, whether natural or human caused, in the components of the climate system and their interactions, may result in climate changes.

Essential Climate Variables

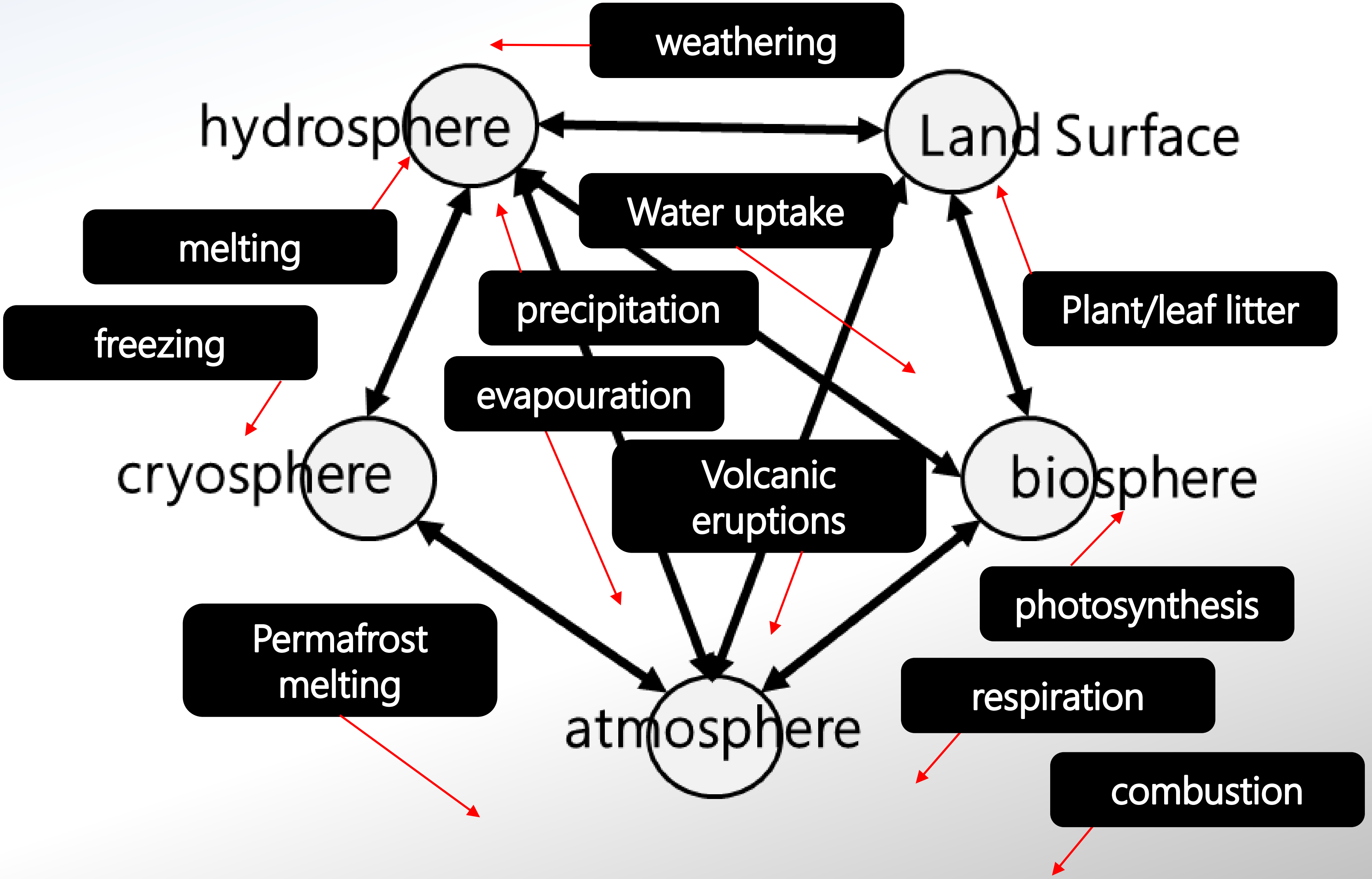
Climate is influenced by **Essential Climate Variables (or signals)** that can be physical, chemical or biological. They include temperature, precipitation, and amounts of solar radiation. Climate is also determined by altitude, longitude, and the distance to large bodies of water, and in contrast to weather, which is normally limited to a smaller area, changes are much more gradual. These are measured to help us understand how the climate is changing

https://public.wmo.int/en/programmes/global-climate-observing-system/essential-climate-variables



Influences on Components of Climate

There are many different interactions that affect the climate – these are just a few. Which processes do you think can be influenced by human activity?



http://godevidences.net/cloud-vectors-free-download.html

What is weather?

Weather is the day-to-day changes in the atmosphere around the earth. The type of weather that is likely in any area is determined by the season (wet/dry or spring/summer/autumn/winter) AND the climate of the area. Weather normally occurs within an expected range of conditions. Extreme weather events are rare events that occur outside the expected range.

Cloud cover

precipitation

temperature

Wind speed

Wind direction

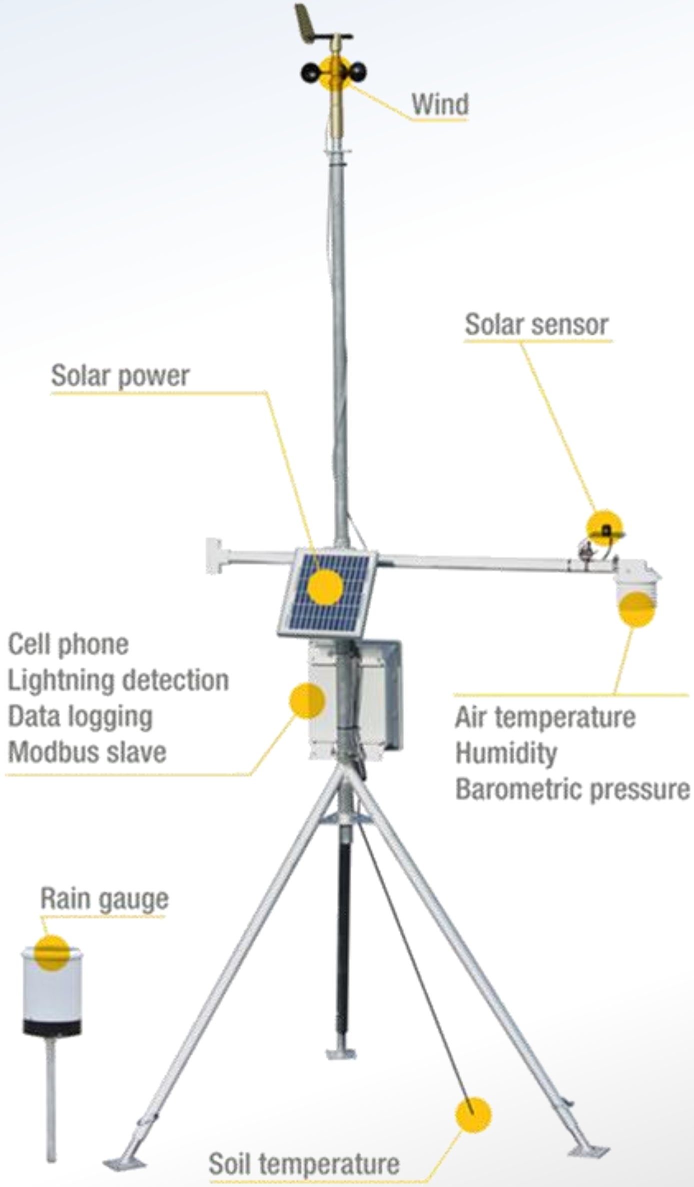
humidity

Air pressure

sunshine

www.freepik.com

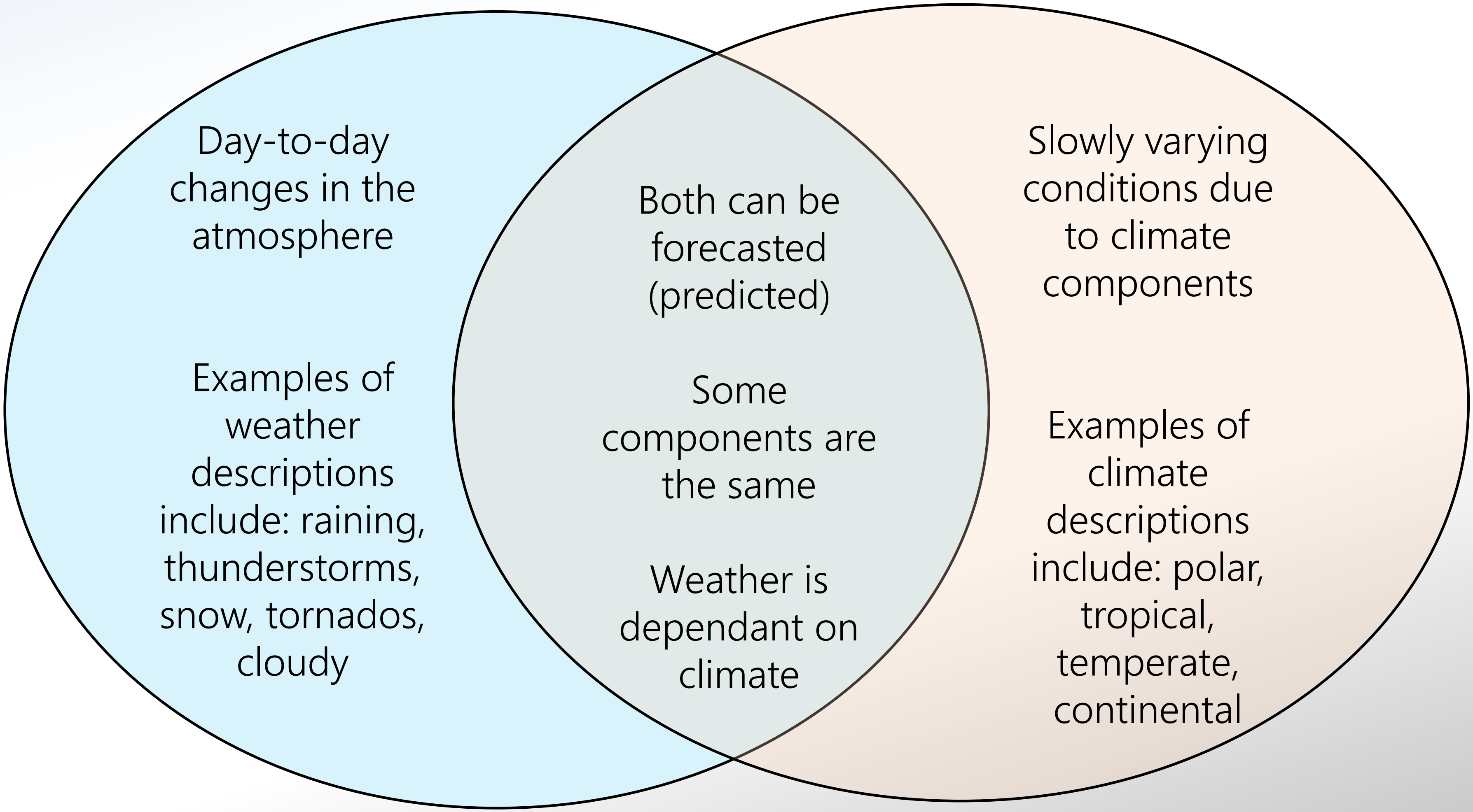
Recording the weather



https://dyacon.com/product/ms-150/

Modern portable weather stations have measuring devices to record not only temperature and amount of rain, but the wind amount and direction, the amount of sunlight and the air pressure. All of this information is saved digitally, and can be sent wirelessly to computers and phones. Before this meteorologists (weather scientists) had to go to stations everyday and take physical readings.

Weather and climate – What's the difference?



weather

climate

Day-to-day changes in the atmosphere

Examples of weather descriptions include: raining, thunderstorms, snow, tornados, cloudy

Both can be forecasted (predicted)

Some components are the same

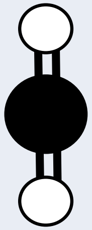
Weather is dependant on climate

Slowly varying conditions due to climate components

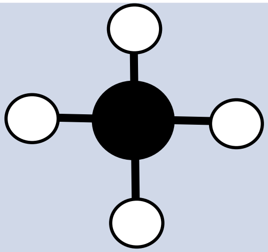
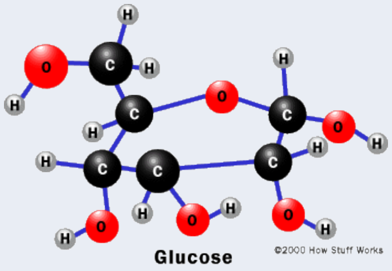
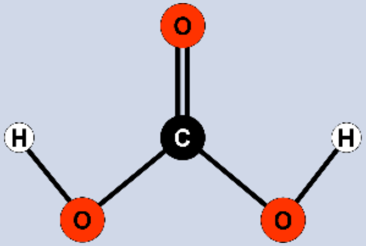
Examples of climate descriptions include: polar, tropical, temperate, continental

Carbon Cycle – Where do we find the carbon?

There is a fixed amount of carbon on Earth, much of it combined with other elements forming compounds, that moves through a carbon cycle, from one reservoir (store) to another, with varying processes and timescales.

Name	Formula	Model	Where is this found on Earth?	What process creates this?
Carbon (graphite/ diamond)	C		underground	Heat and pressure from underground, originally from coal
carbon dioxide	CO_2		In the atmosphere	Combustion respiration
Calcium carbonate	$CaCO_3$		In marine/snail shells In rocks like limestone and marble	Biological shell building Pressure and heat on shells underground

Carbon Cycle – Where do we find the carbon?

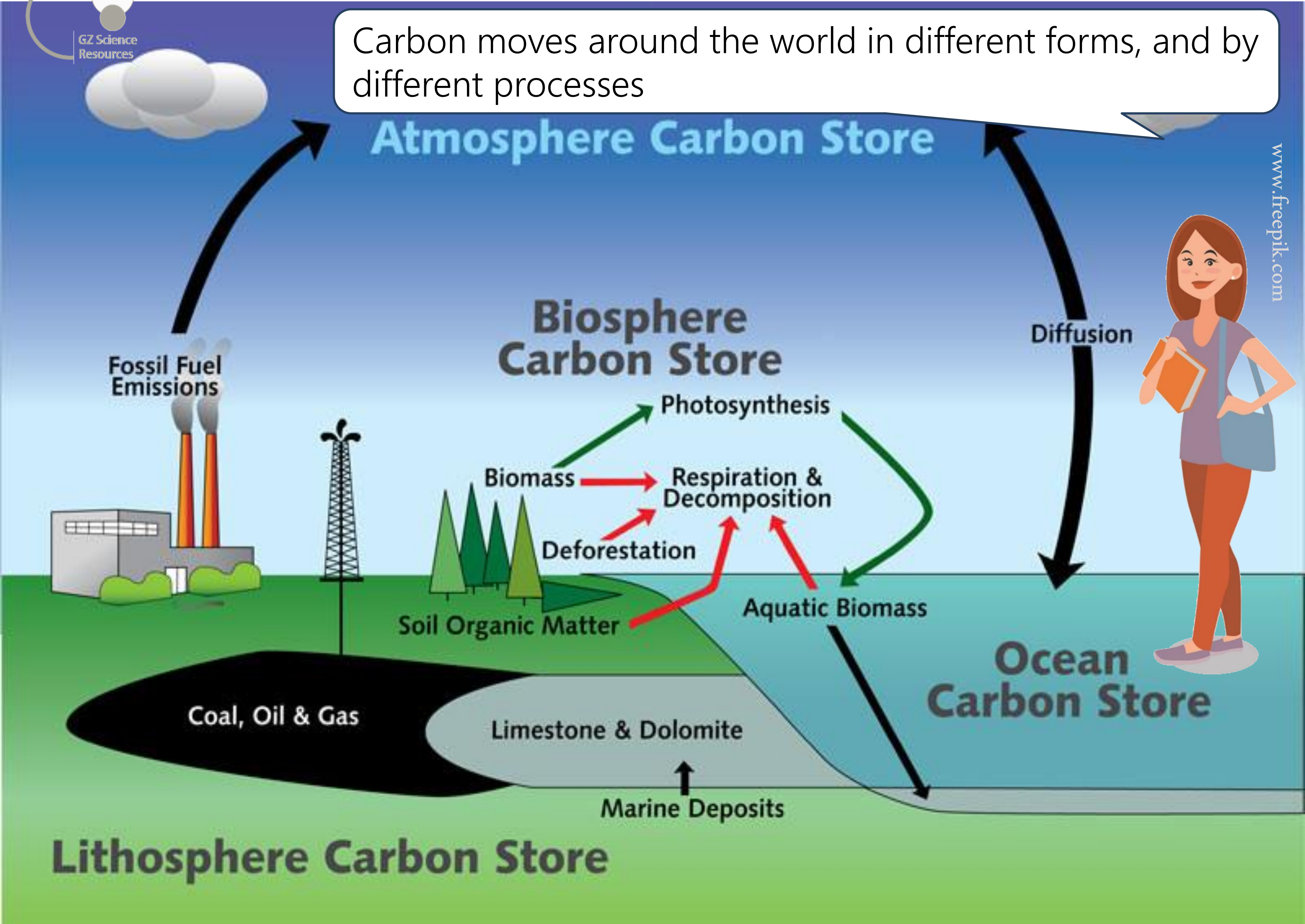
Name	Formula	Model	Where is this found on Earth?	What process creates this?
methane	CH_4		In the atmosphere In permafrost (frozen ground) Underground	Decomposition dead plants and animals)
Glucose	$C_6H_{12}O_6$	 Glucose ©2000 How Stuff Works	In plants In animals	Photosynthesis Transfer from plants to animals by eating
carbonic acid	H_2CO_3		In oceans In the air/atmosphere	CO_2 reacting with water in the oceans CO_2 Reacting with water in the atmosphere

Carbon Cycle – Where do we find the carbon?

Name	Formula	Model	Where is this found on Earth?	What process creates this?
oil	Carbon and hydrogen molecules		underground	Fossilised sediment remains of marine animals, heat and pressure underground
coal	Mostly carbon		Underground, open cast mines	Fossilised remains of plants, heat and pressure underground

The Carbon Cycle

Carbon moves around the world in different forms, and by different processes



The carbon Cycle

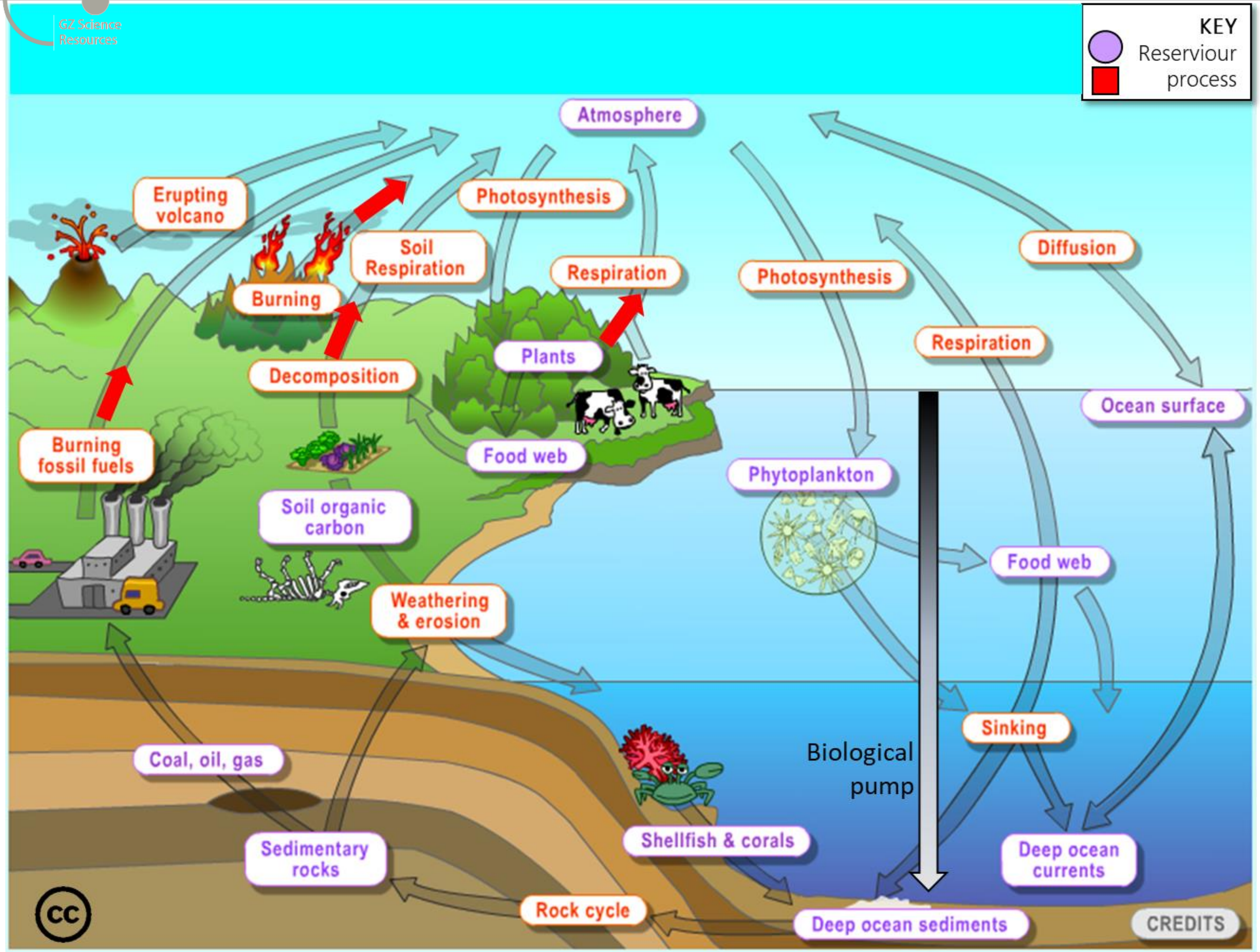
Carbon stores (***reserviours)*** are ‘areas’ where carbon, often contained within compounds, are naturally stored on Earth. The atmosphere is a reserviour where carbon is stored in the form of carbon dioxide gas (CO_2). However, this is one the smallest carbon reservoirs, where CO_2 makes up only 0.03% of the atmospheric gases. Another reserviour is held within biological sources, such as trees and fossil fuels. The largest reservoir of carbon is in ocean water, which also acting as a ***carbon sink***, with a <u>net</u> movement (more in one direction than the other) of carbon into the ocean from the atmosphere. The atmosphere acts as a ***source***, where the carbon originates from.

vecteezy.com

www.freepik.com

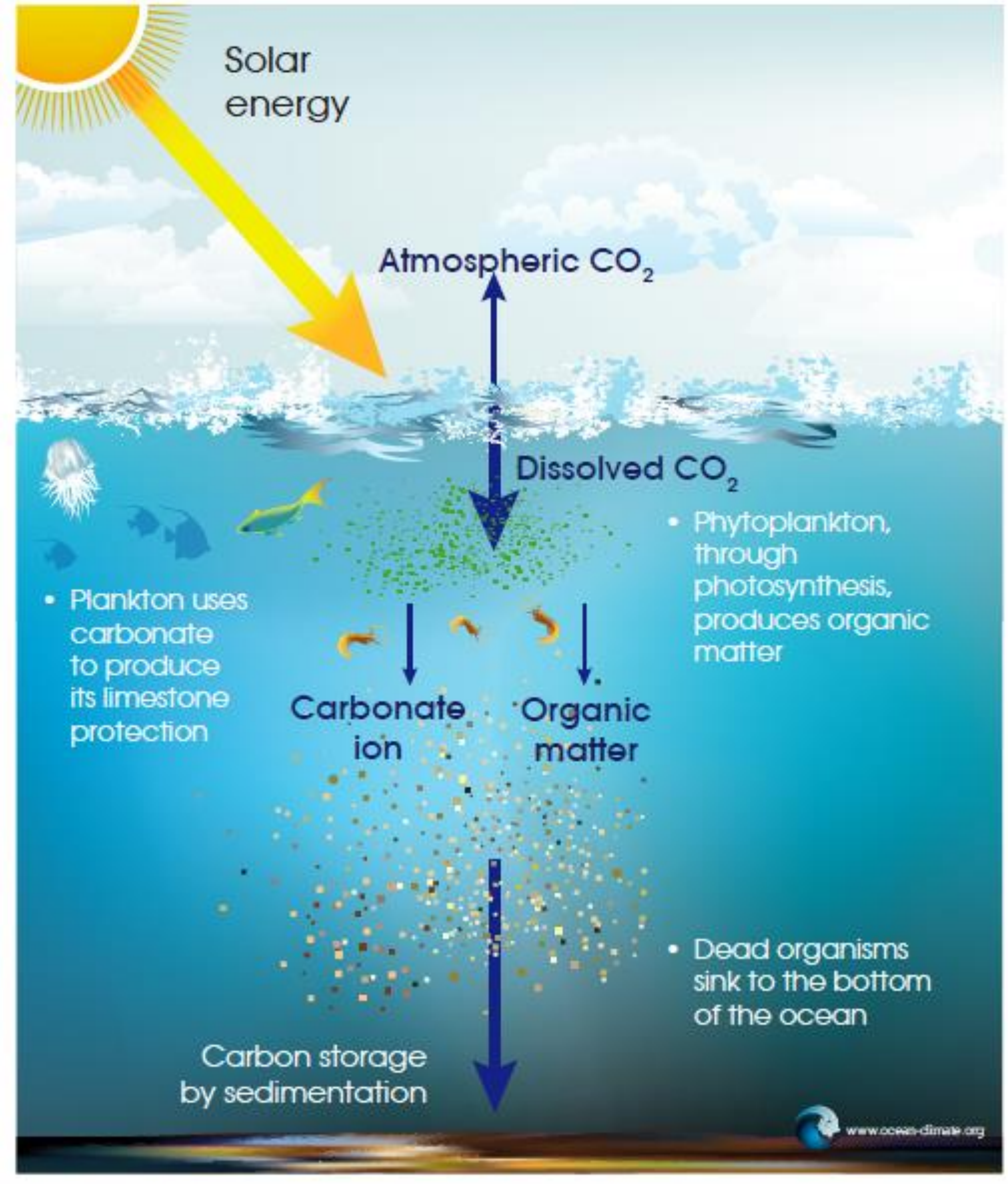
https://serc.carleton.edu/download/images/56944/global_carbon_cycle_1427132279.jpg

The Detailed Carbon Cycle



The ocean, as a biological pump

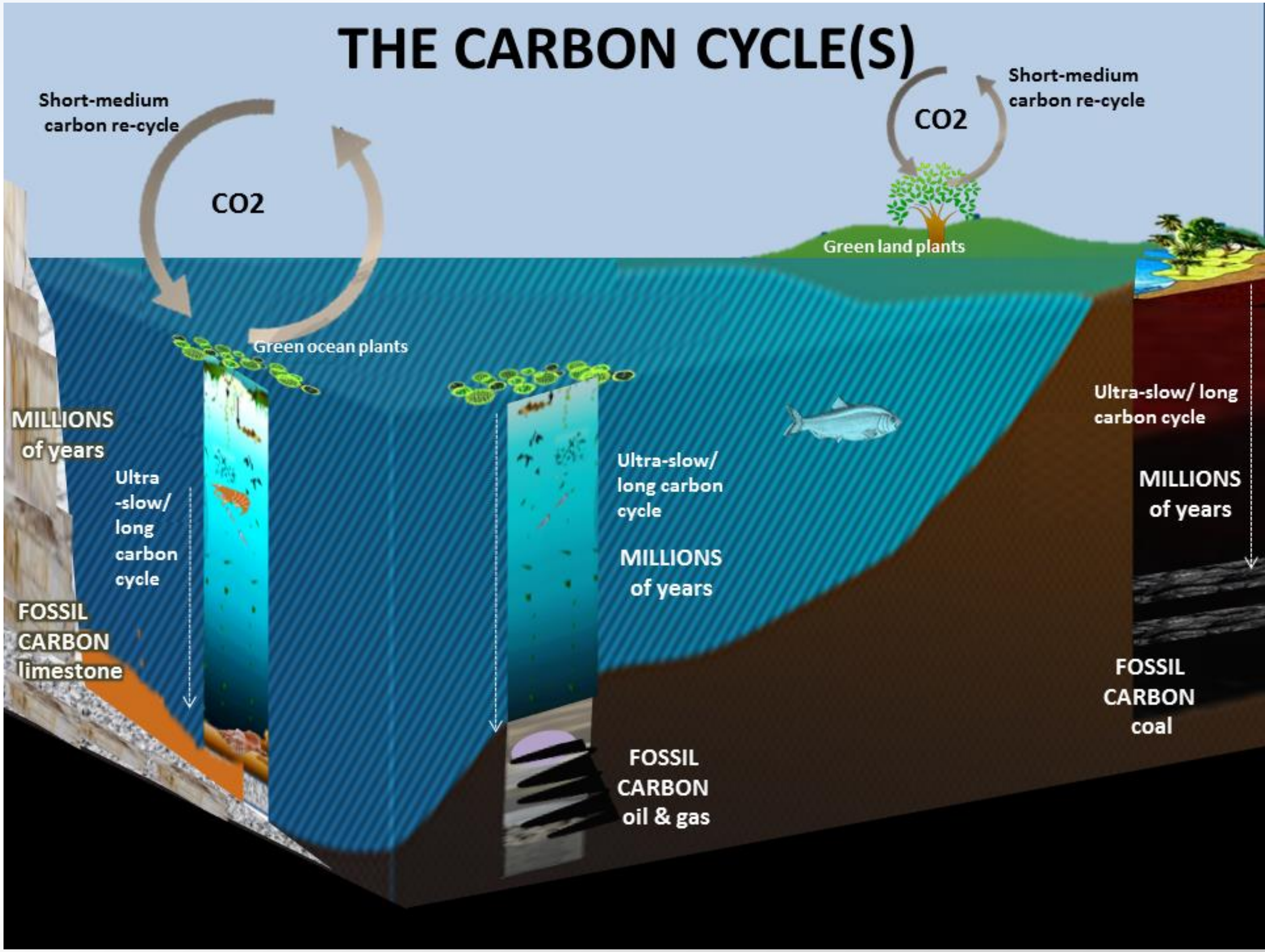
Once in the ocean, carbon enters the marine food chain via photosynthesis, as well as being utilised for invertebrate (without internal skeleton) shells and outer skeletons made by calcifiers, such as marine molluscs and microorganisms. This *sequestration* (storing away) mechanism acts as a *biological pump,* with carbon moving in one direction through the ocean's organisms.



https://oceans.taraexpeditions.org/en/m/science/news/plankton-network-linked-to-oceans-biological-carbon-pump-revealed/

Fossil fuels as a (store) reserviour

Carbon from the sedimentary remains of marine organisms becomes locked up, often for millions of years, once it is processed into rocks, such as limestone, and fossil fuel carbon reservoirs, with coal forming from ancient plant remains, and natural gas and oil from marine organisms.

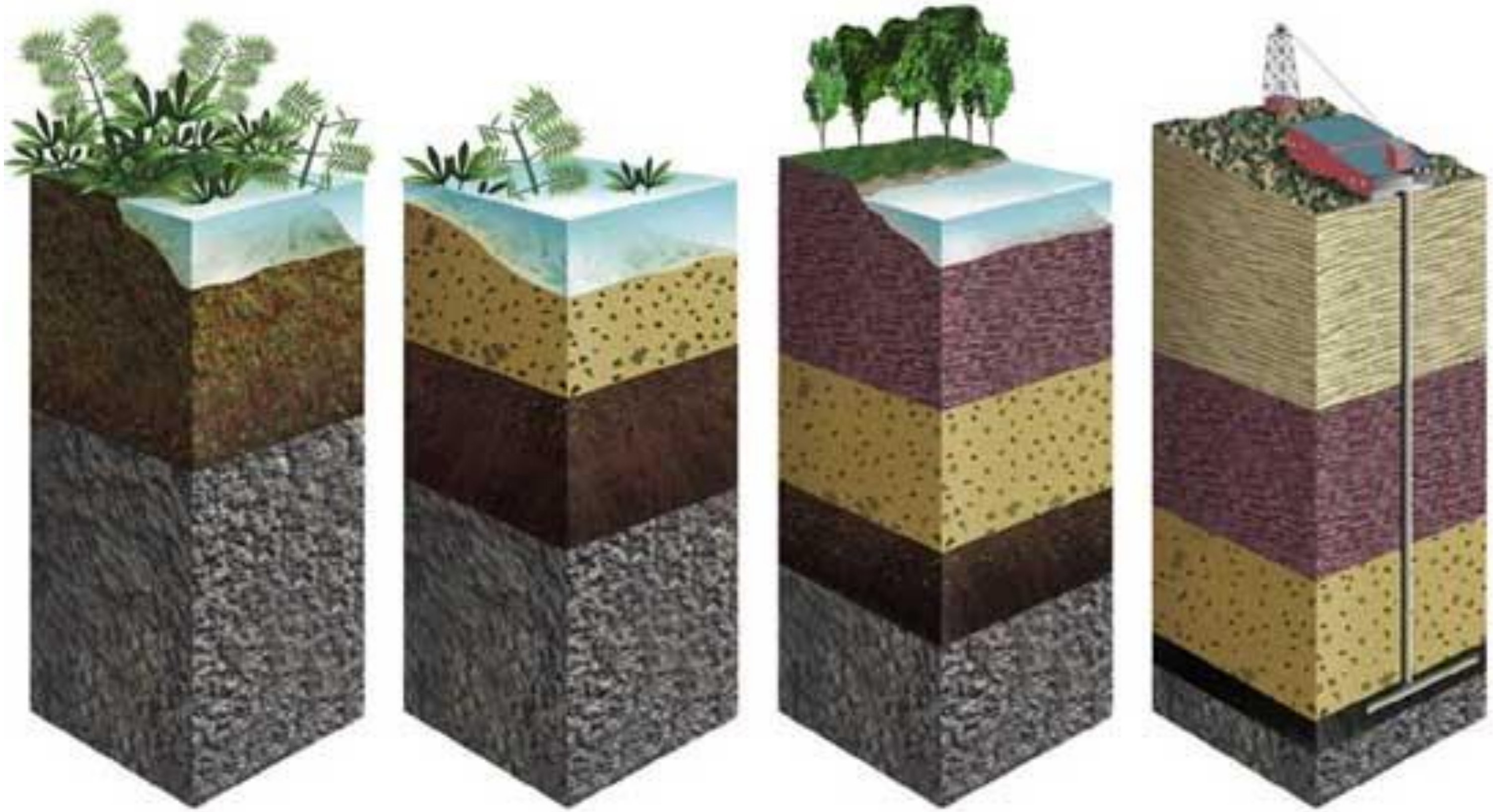


https://www.climateemergencyinstitute.com/committed_climate_change.html

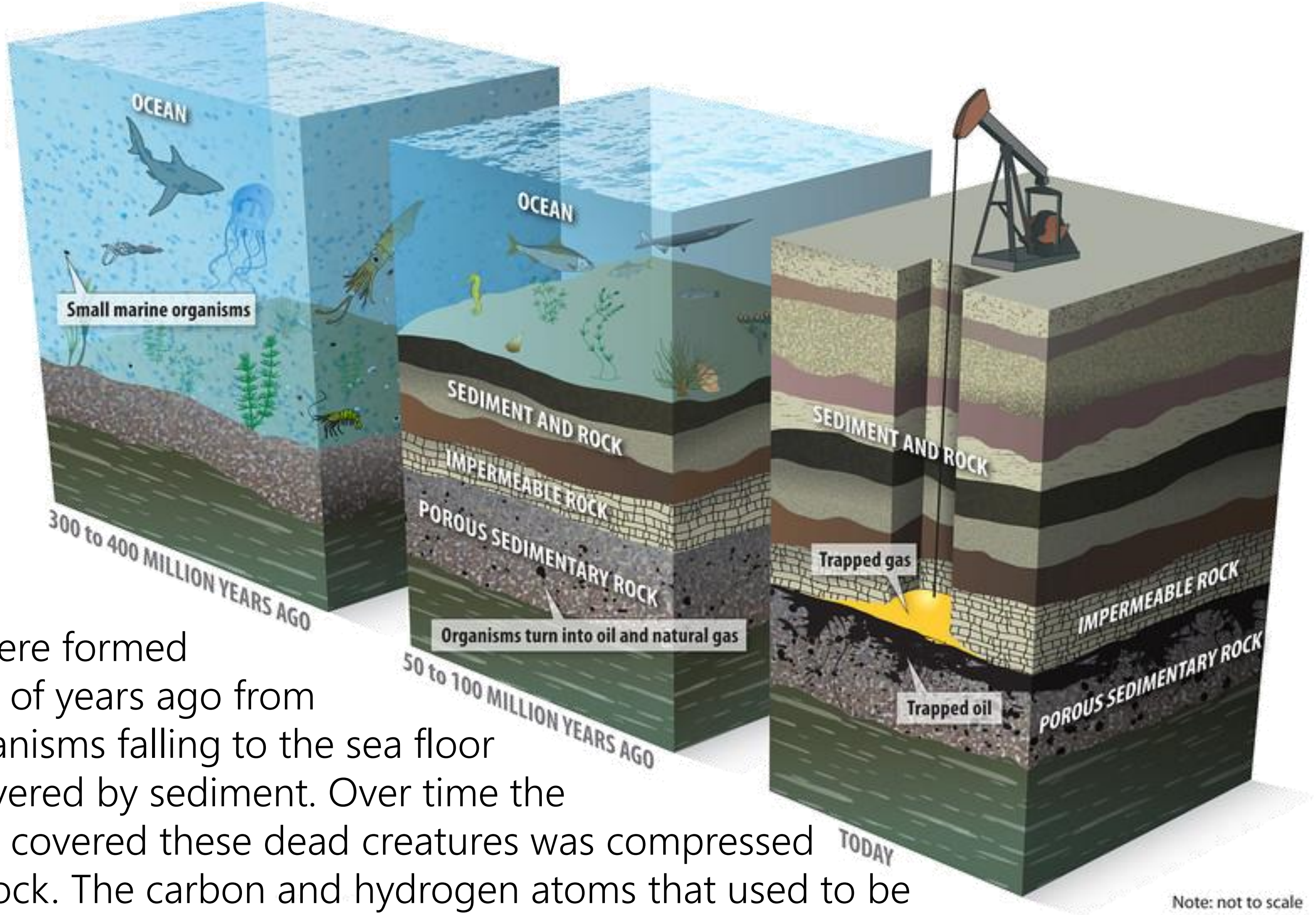
Fossil fuels – forming coal

Coal was formed millions of years ago when plants fell into peat swamps and were buried by heavy earth and rocks. Over millions of years, the weight of the rocks and heat in the ground turned the plants into coal.

Most of the world's coal was formed 300–350 million years ago during the **Carboniferous** period that was warm and damp, ideal for plant growth. New Zealand coals are much younger – they were made 30–70 million years ago and they are a less energy rich fuel. Coal is mined either underground or in large open cast mines.



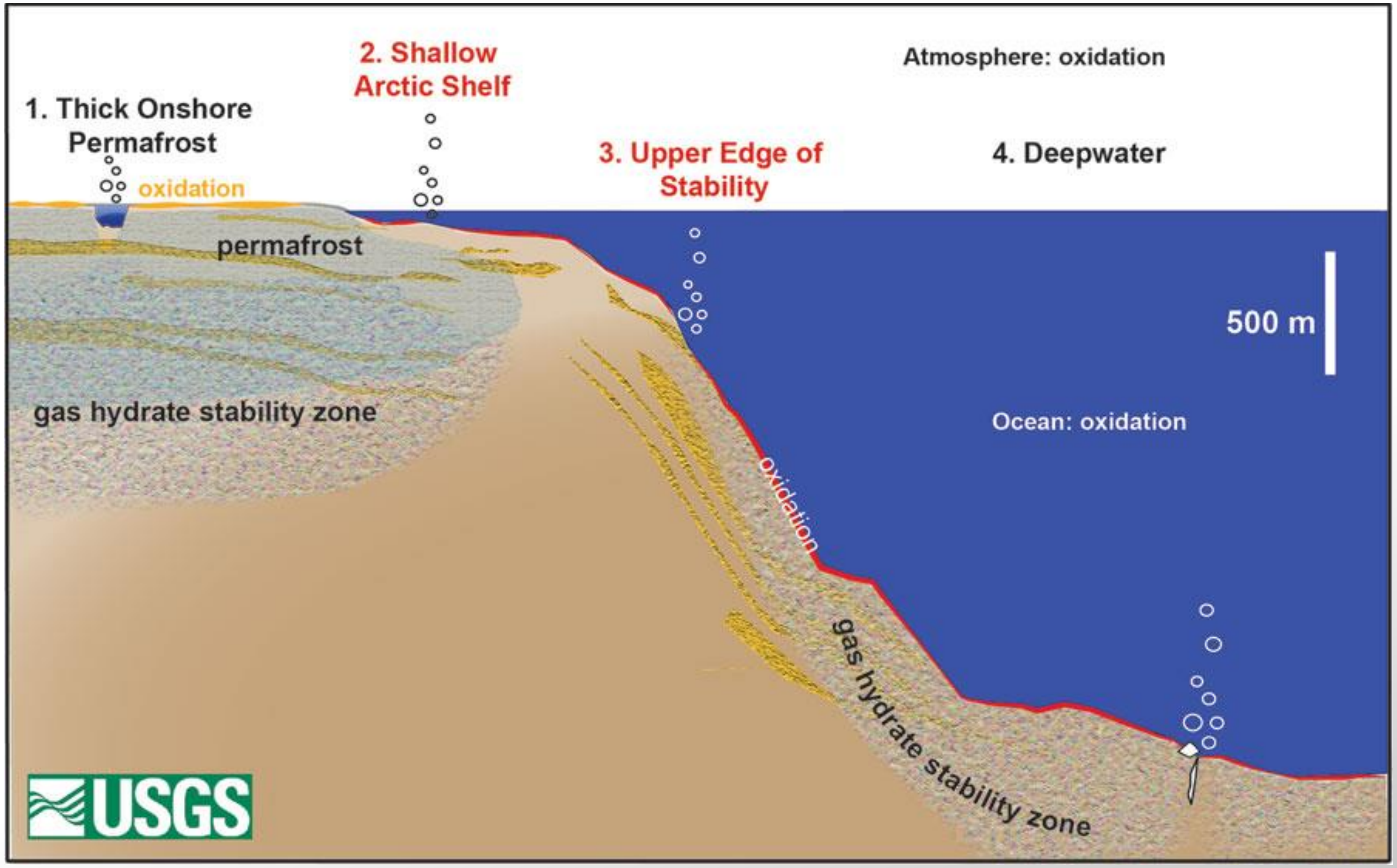
Fossil fuels – Forming oil



Oil and gas were formed many millions of years ago from dead sea organisms falling to the sea floor and being covered by sediment. Over time the sediment that covered these dead creatures was compressed and formed rock. The carbon and hydrogen atoms that used to be part of the dead organisms bodies reformed into fuel – the liquid form called oil and the gas form. Oil and gas are mined by drilling deep into the ground from oil rigs.

Stored Methane, as a carbon reserviour

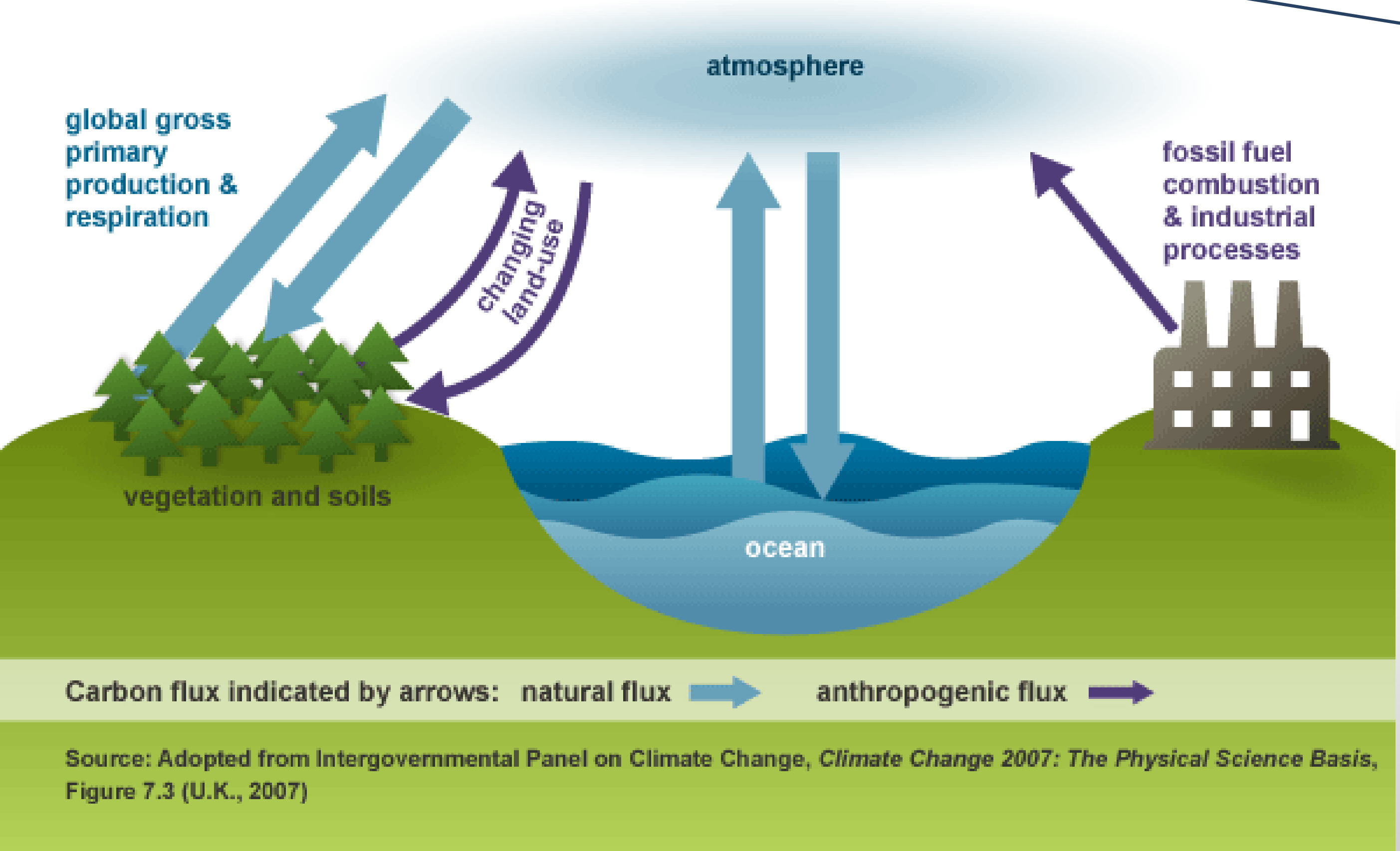
Methane (CH_4), mostly formed through biological processes, is a potent greenhouse gas found in the atmosphere, in permafrost *(frozen ground)* near the poles, and also stored under the sea floor in the form of hydrates, *stabilised* by pressure and stable cool temperatures



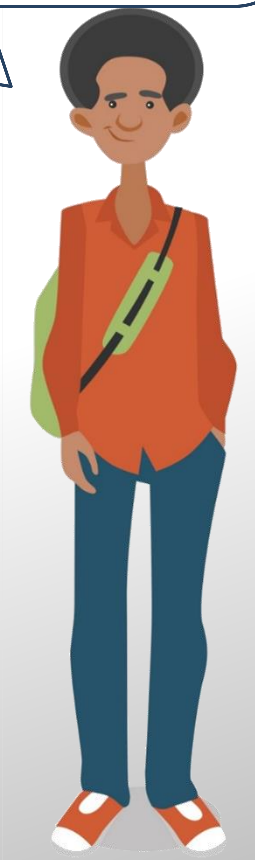
http://climatestate.com/2014/01/03/usgs-climate-hydrate-interactions/

Human influence on the carbon cycle

Human activity is increasing the net flow of carbon from other reservoirs into atmospheric CO_2. Human (anthropogenic) caused combustion (burning) of fossil fuels accounts for the greatest change to the carbon cycle in the post-industrial age (the time after 1780's when humans started using engines to power industry), which converts (changes) most of the carbon locked up in oil, gas, or coal, into CO_2 released into the atmosphere. Changing land-use can influence the total CO_2 emissions as well.



Source: Adopted from Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis*, Figure 7.3 (U.K., 2007)



The evidence for Human influence on the carbon cycle

Past records from ice cores (seen below) show that the level of CO_2 in the atmosphere is higher than at any time since humans have been on Earth. “Carbon dioxide concentrations [in the atmosphere] have increased by 40 per cent since pre-industrial times” and currently sits at around 406ppm (parts per million).

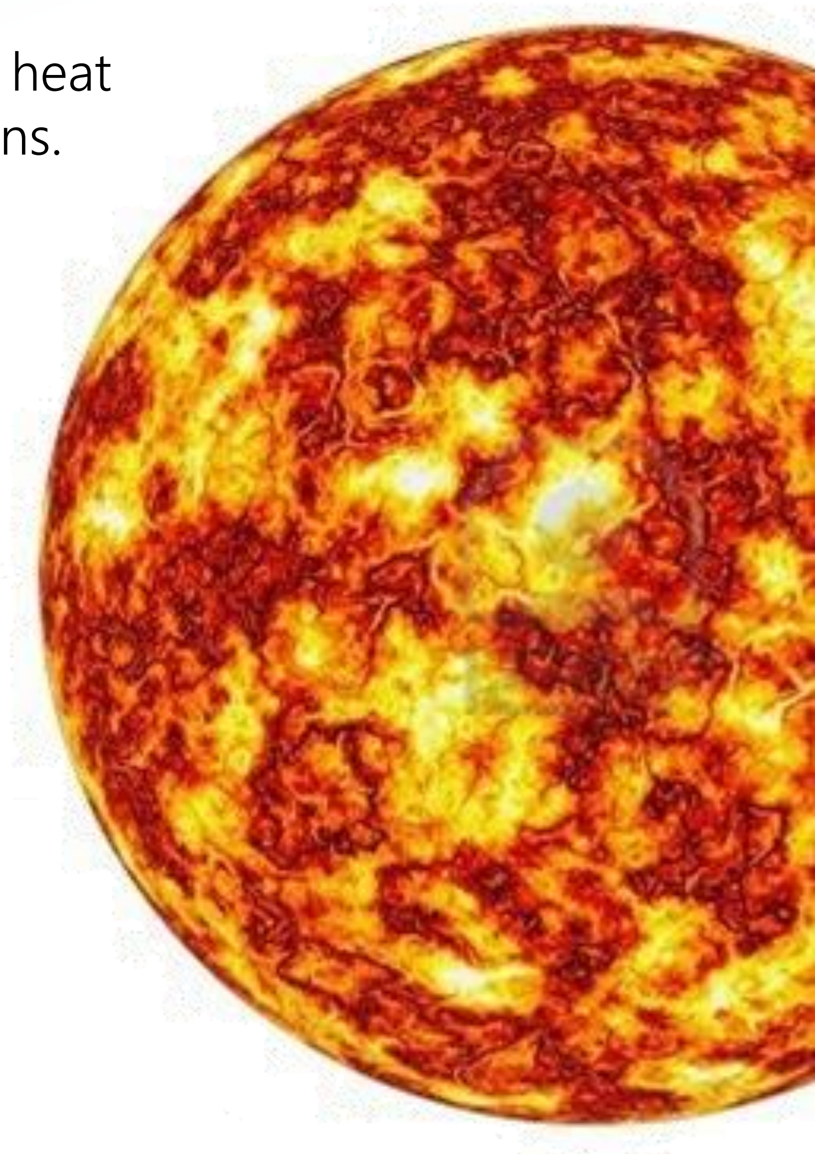
https://nsidc.org/cryosphere/icelights/2013/08/core-climate-history

Earth’s Energy comes from the Sun

A star is a mass of extremely hot gas. It emits heat and light energy produced by nuclear reactions.

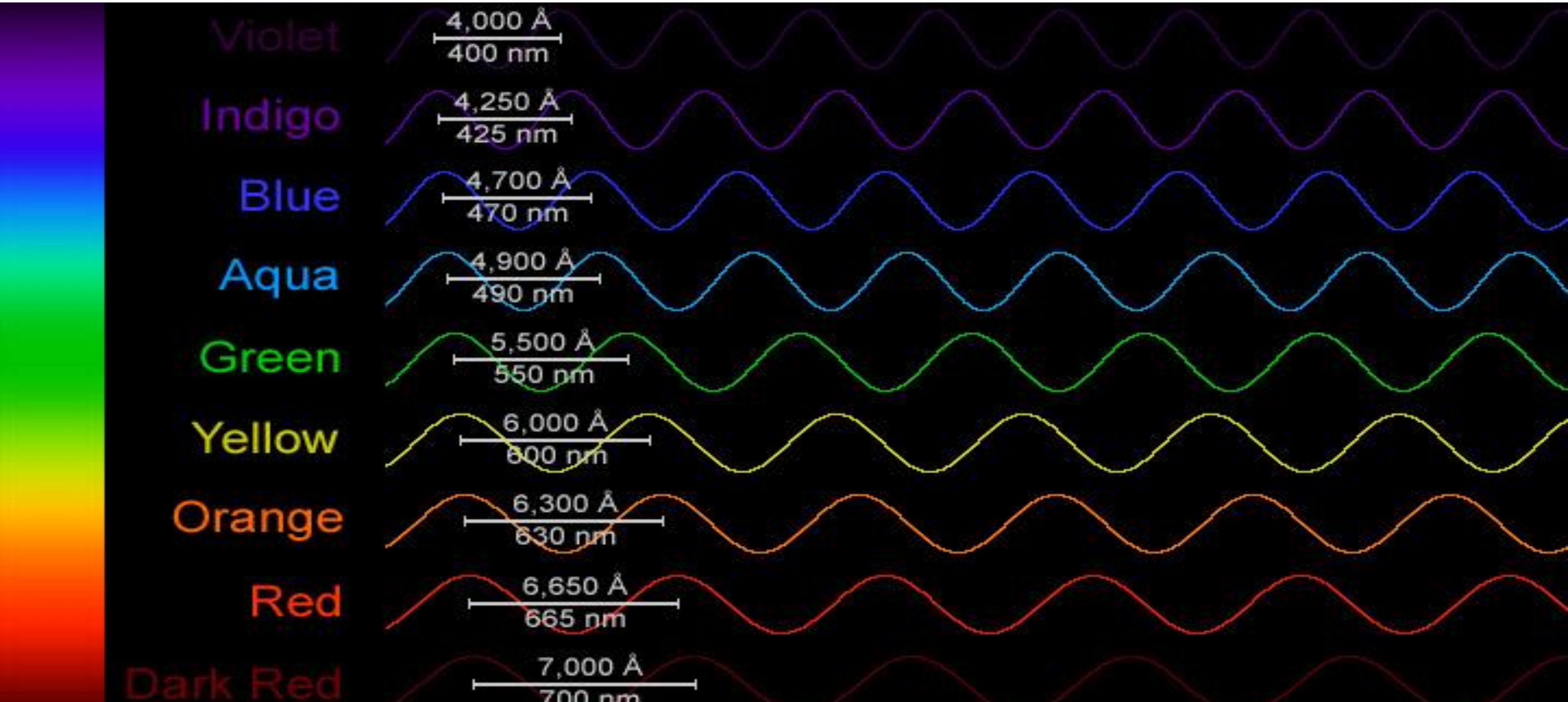
The sun consists of extremely hot gases held together in a sphere by gravity. Nuclear reactions occur inside the sun. Hydrogen is changed into helium and huge amounts of energy are released. The interior temperature is 14 million °C, and the surface temperature is 5,800 °C.

The nuclear (fusion) reaction inside the Sun generates electromagnetic radiation in the form of energy: heat (infrared), light (visible), radio waves, Ultra violet. The Sun does make X-rays but our atmosphere stops them from reaching Earths surface.



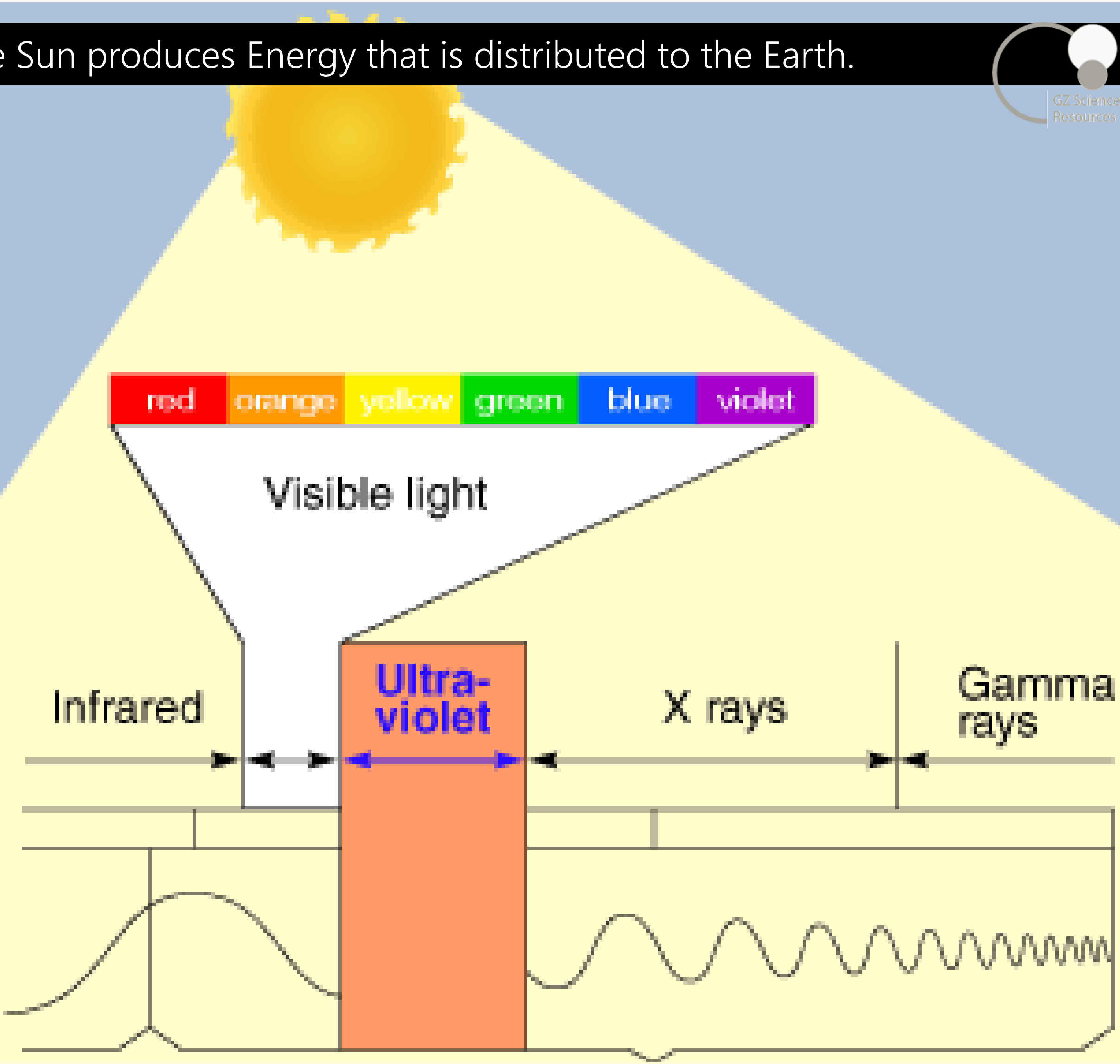
Energy can be transferred as waves.

Light and other types of electromagnetic radiation from the sun and even further away stars travel through space in a vacuum – an area of very little or no atoms. Light does not need matter or a substance through which to travel. Each particular type of electromagnetic radiation, including each different colour of light, has a unique fixed length of wave, called the **wavelength** (λ), that it travels in.



The Sun produces Energy that is distributed to the Earth.

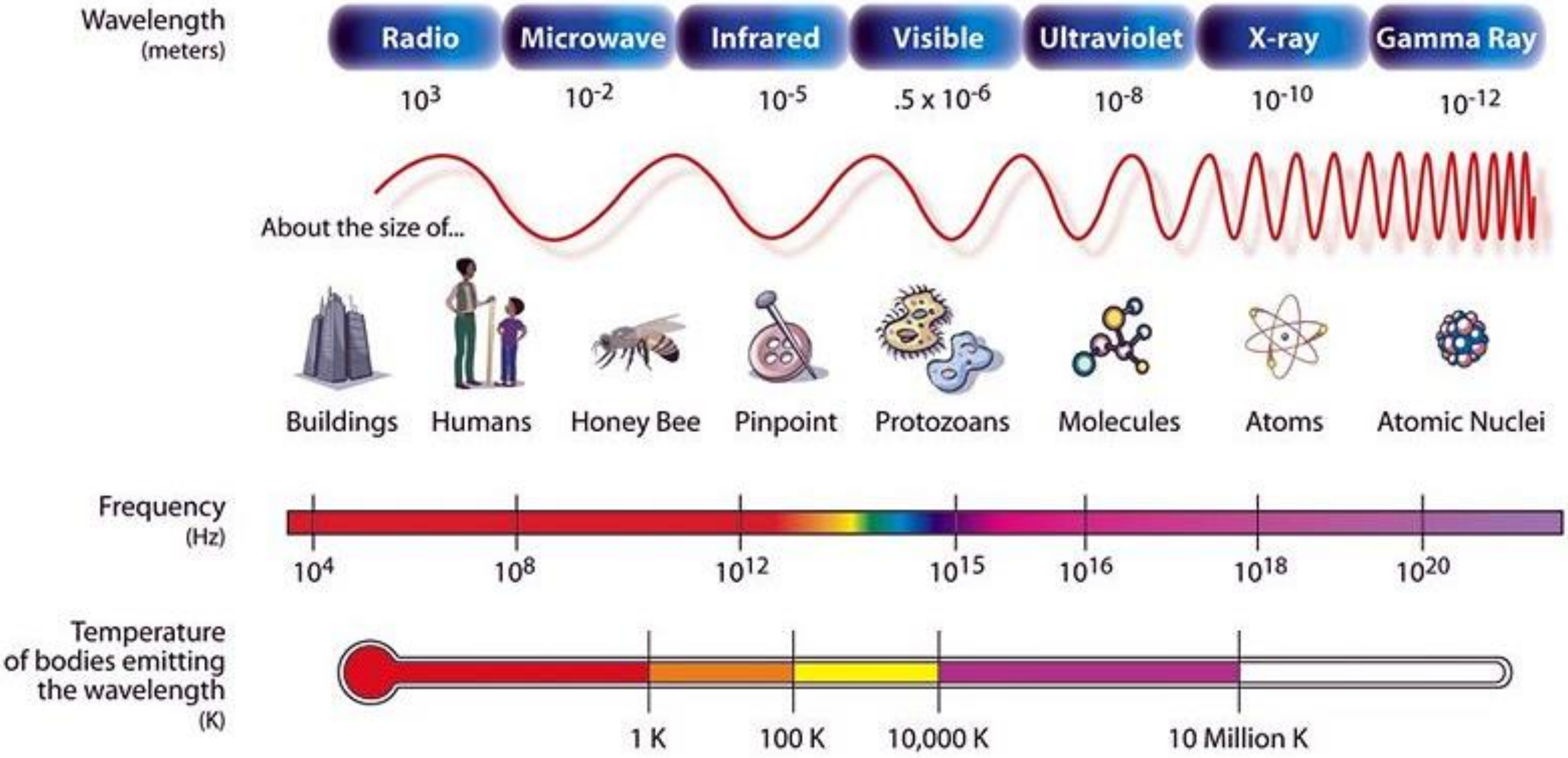
The Sun releases large amounts of energy. The energy can be **emitted** from the energy source in the form of **electromagnetic radiation** and travels in **electromagnetic waves.** Heat (infrared) is long wave radiation, Light is short wave radiation.



← Long wave radiation | Short wave radiation →

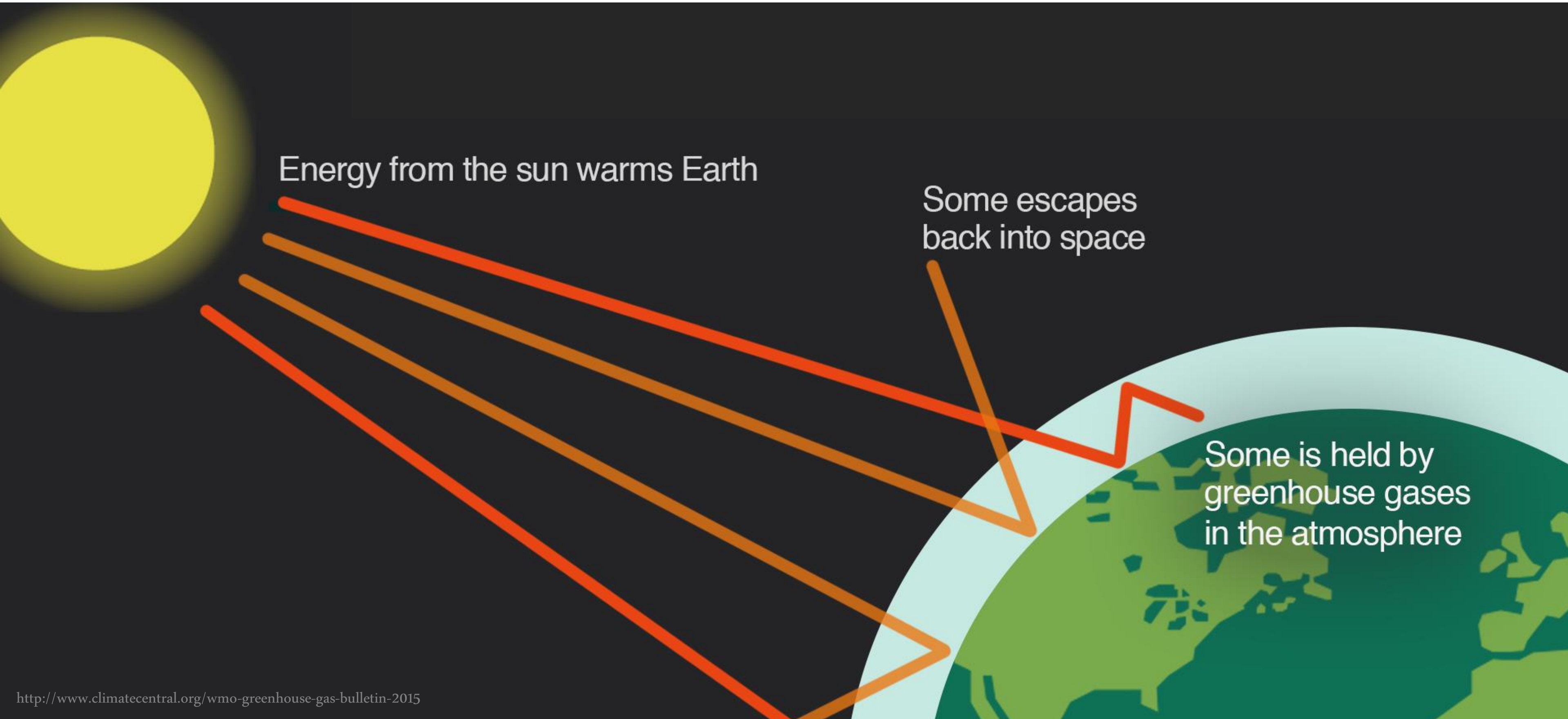
Heat (infrared) radiation has a longer wavelength than light

The temperature of the body (source) determines the main type of radiation that is emitted. The Earth is cooler than the Sun, so mainly emits heat, travelling long wavelengths.



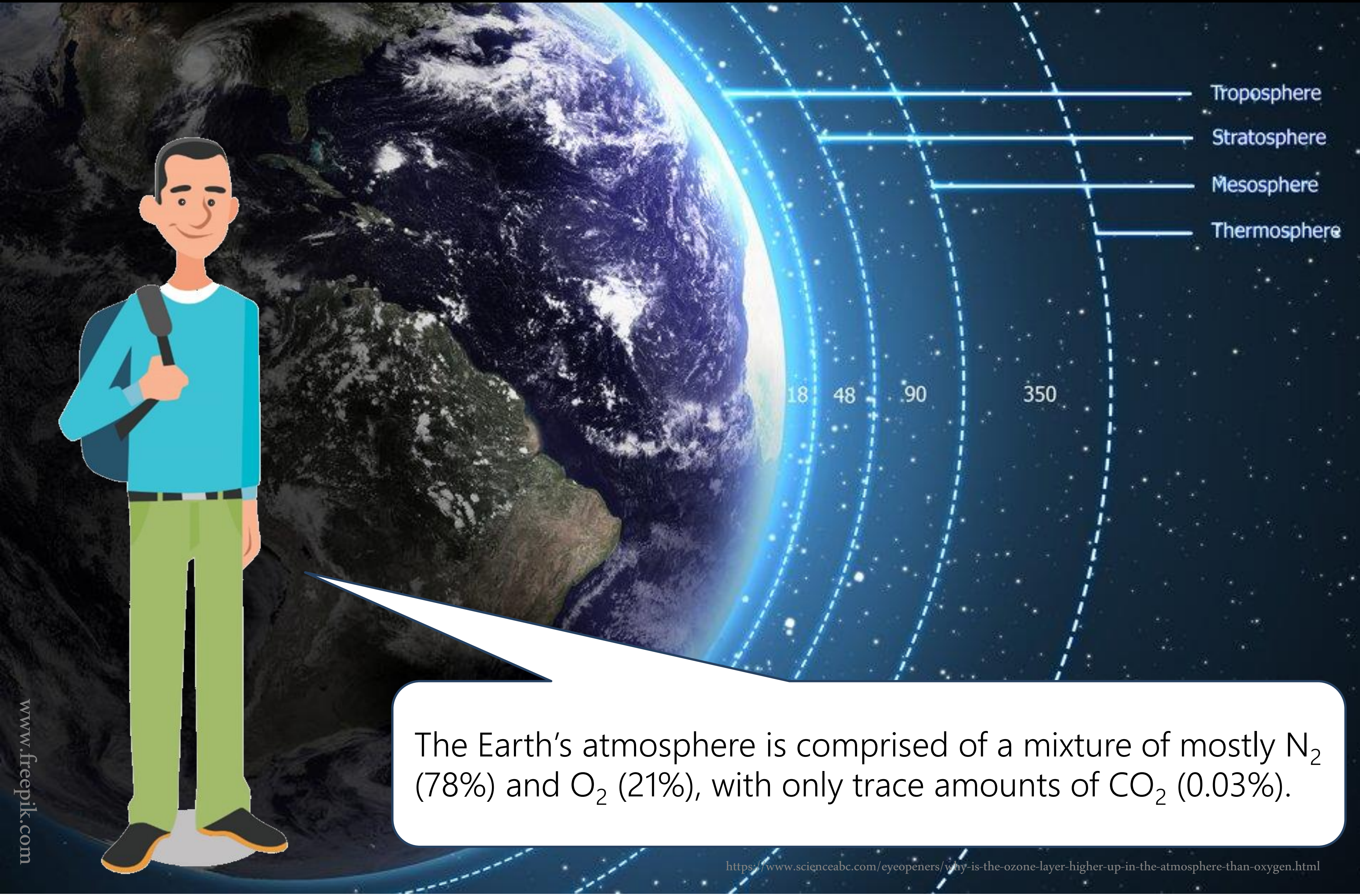
Energy moving around the Earth

The short wavelength radiant energy from the Sun travels with little resistance through the Earth's atmosphere until it reaches the surface, where it is absorbed, and then most of the energy re-radiated. The Earth is much cooler than the Sun, so energy travels in longer wavelengths, mostly as infrared radiation (heat).



http://www.climatecentral.org/wmo-greenhouse-gas-bulletin-2015

The atmosphere

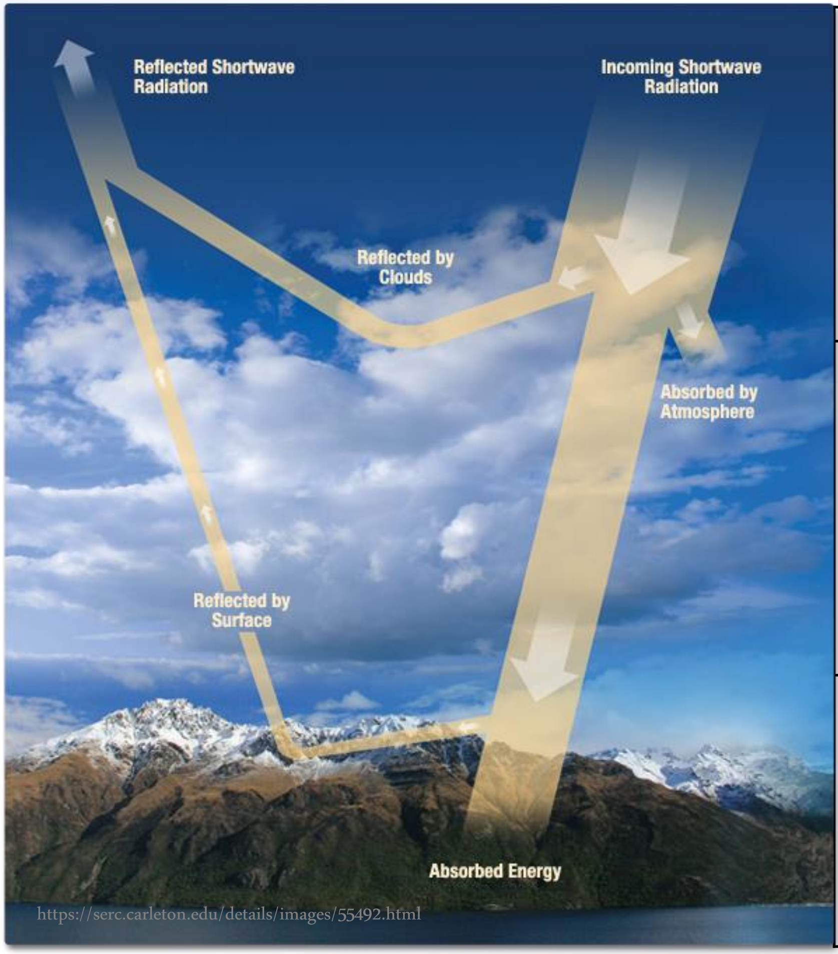


The Earth’s atmosphere is comprised of a mixture of mostly N_2 (78%) and O_2 (21%), with only trace amounts of CO_2 (0.03%).

https://www.scienceabc.com/eyeopeners/why-is-the-ozone-layer-higher-up-in-the-atmosphere-than-oxygen.html

Calculating Earth's Energy Budget

The Energy Budget calculates the total amount of energy entering the Earth's atmosphere (as light energy), and subtracts the total amount leaving (as light and heat). The amount of energy left over will cause the atmosphere to heat.



https://serc.carleton.edu/details/images/55492.html

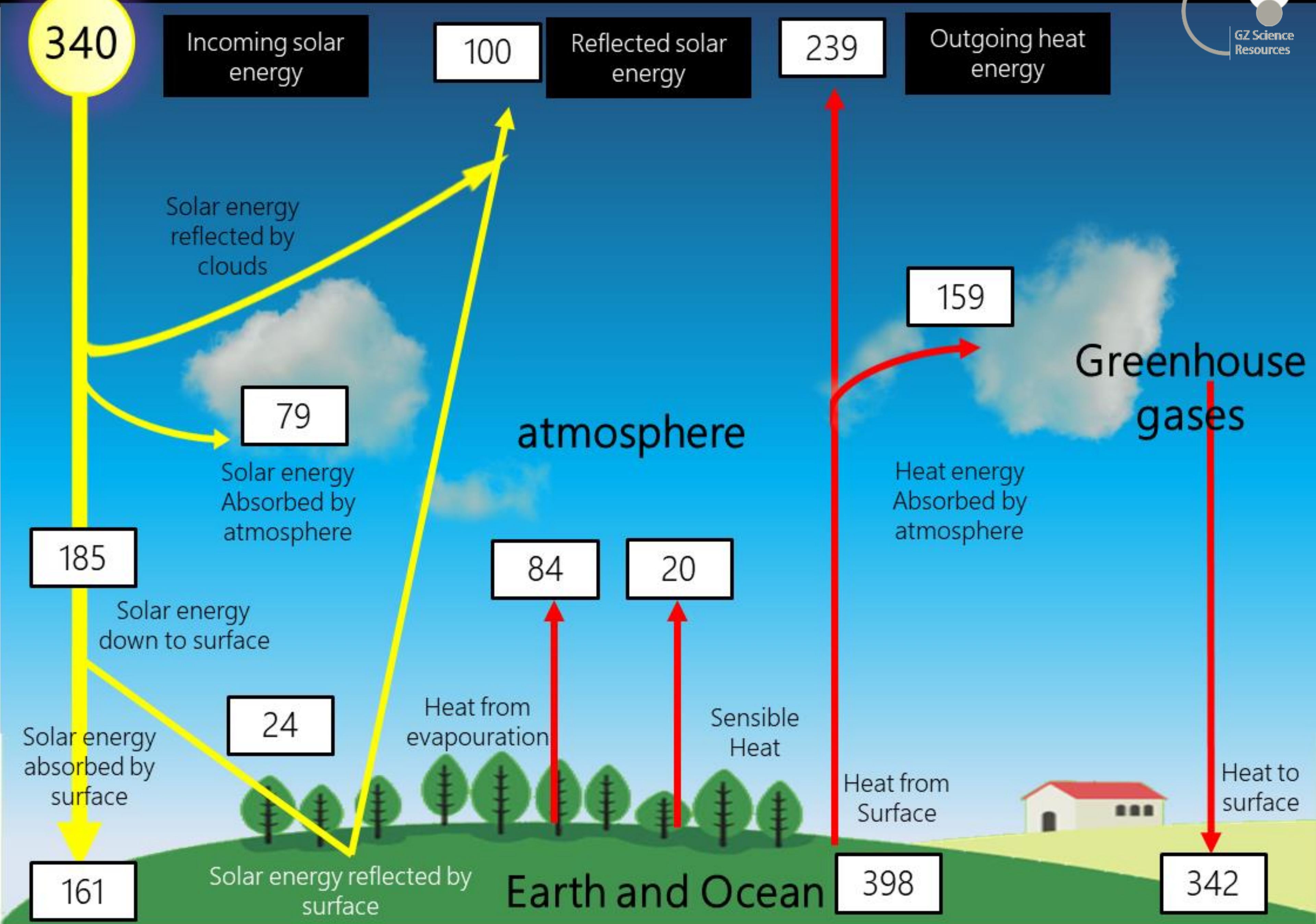
Total of all Solar (light) energy into Earth's atmosphere	340	Total of all outgoing solar (light) energy from Earth's atmosphere	100
		Total of all heat (thermal) energy leaving Earth's atmosphere	239
TOTAL of all energy reaching Earth's atmosphere	340	TOTAL of all energy leaving Earth's surface	339

Difference in energy IN and energy OUT 1 w/m^2 into Earth's atmosphere

Earth's Energy Budget

Energy budget values based on IPCC AR5

GZ Science Resources



340 Incoming solar energy

100 Reflected solar energy

239 Outgoing heat energy

Solar energy reflected by clouds

79 Solar energy Absorbed by atmosphere

atmosphere

159 Greenhouse gases

Heat energy Absorbed by atmosphere

185 Solar energy down to surface

84 Heat from evapouration

20 Sensible Heat

24

Solar energy absorbed by surface

161

Solar energy reflected by surface

Earth and Ocean

398 Heat from Surface

342 Heat to surface

Calculating Earth's Energy Budget (advanced)

Total of all Solar (light) energy down to Earth's surface	185	Total of all solar (light) energy reflected from Earth	24
Total of all heat (thermal) energy to Earth's surface	342	Total of all heat (thermal) energy leaving Earth	502
TOTAL of all energy reaching Earths surface	527	TOTAL of all energy leaving Earth's surface	526

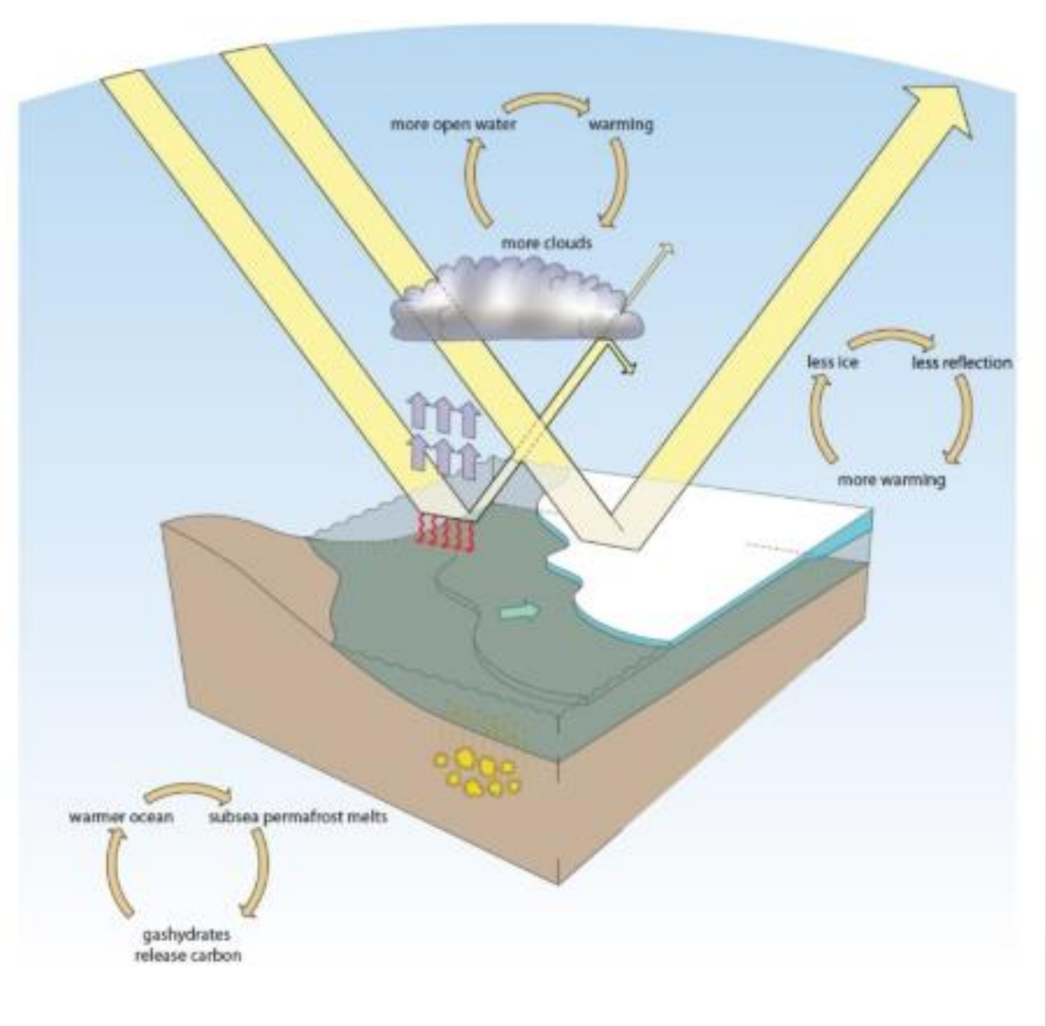
Difference in energy IN and energy OUT 1 w/m^2 into Earth's surface

The energy budget shows the energy amounts (in w/m^2 watts per metre^2) moving in and out of the Earth. Yellow indicates light (SW) radiation, and red indicates heat (LW). If the total amount of energy coming in = energy going out is the same, then the energy budget is balanced and there will be no temperature increase.

morevectors.com

Albedo Effect

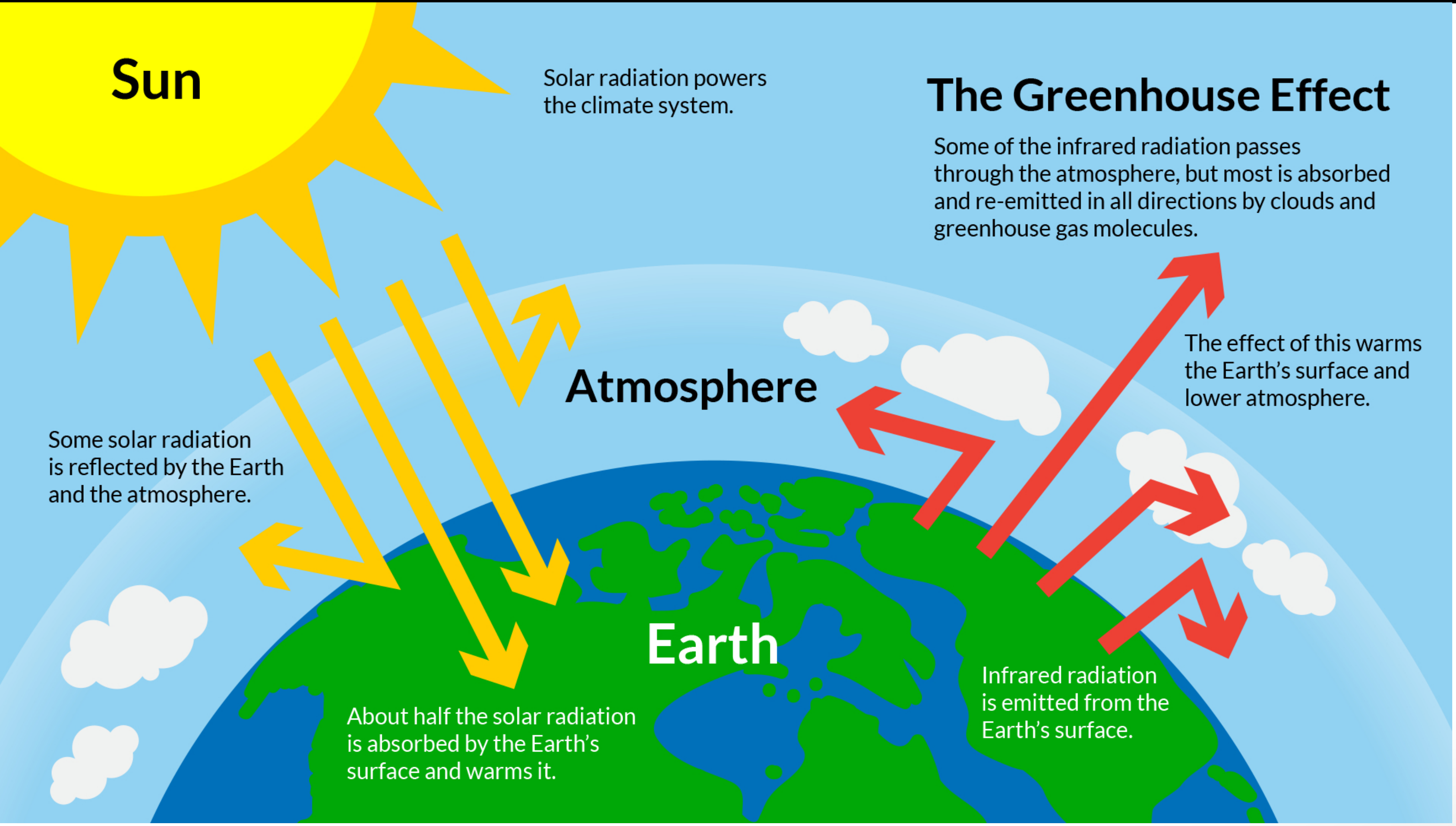
Short wave radiation (light), **is** either **reflected** or **absorbed** when it reaches the ground.
White and silver objects **reflect** radiation and very little heat energy is transferred to them, called the albedo effect. Black objects **absorb** radiation and a large proportion of the heat energy is transferred to them. The disappearance of surface ice and snow is reducing the albedo, revealing dark rock or water, therefore, a significantly higher amount of energy is absorbed rather than reflected.



http://www.npolar.no/en/facts/albedo-effect.html

This increases the average temperature near the polar areas, and induces even further melting of the ice and snow.

The Greenhouse Effect



Greenhouse Gases Diagram Fileearths Greenhouse Effect Us Epa 2012 Wikimedia Commons intended for Greenhouse Gases Diagram.

CO_2, H_2O, and methane (CH_4) gases in the atmosphere are able to *absorb* and *emit (send out)* long wavelength energy (Heat), causing the atmosphere to heat up. The more greenhouse gases, the more energy is kept than released back out into space. This is the principle of the *greenhouse effect.*

The *greenhouse effect* is **very important for life on earth**. Without it Earth would be too cold to support life. Even during night time, when that half of the Earth's surface is facing away from the Sun, enough heat is retained to keep it warm.

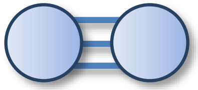
Greenhouse Gases

The gases that absorb the infrared radiation are known as greenhouse gases. Some gases, such as O_2 and N_2 are insignificant in regards to the greenhouse effect, due to their particular molecular structure. CH_4 and H_2O are 'stronger' GHG than CO_2, but due to the shorter time they stay in the atmosphere they have less influence. H_2O cycles rapidly through the atmosphere and CH_4 breaks down after around 12 years, compared to CO_2, which remains for hundreds of years.

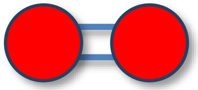
Gases in the atmosphere

Inflexible, little capacity to move and absorb energy

nitrogen (N_2)



oxygen (O_2)

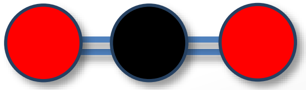


Not greenhouse gases

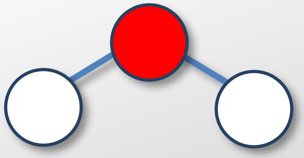
greenhouse gases

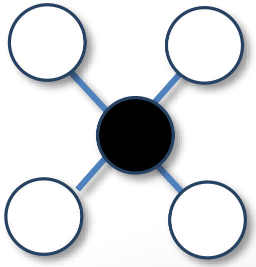
Flexible bonds, can move and absorb energy

carbon dioxide (CO_2)

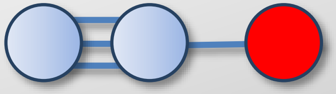


water (H_2O)





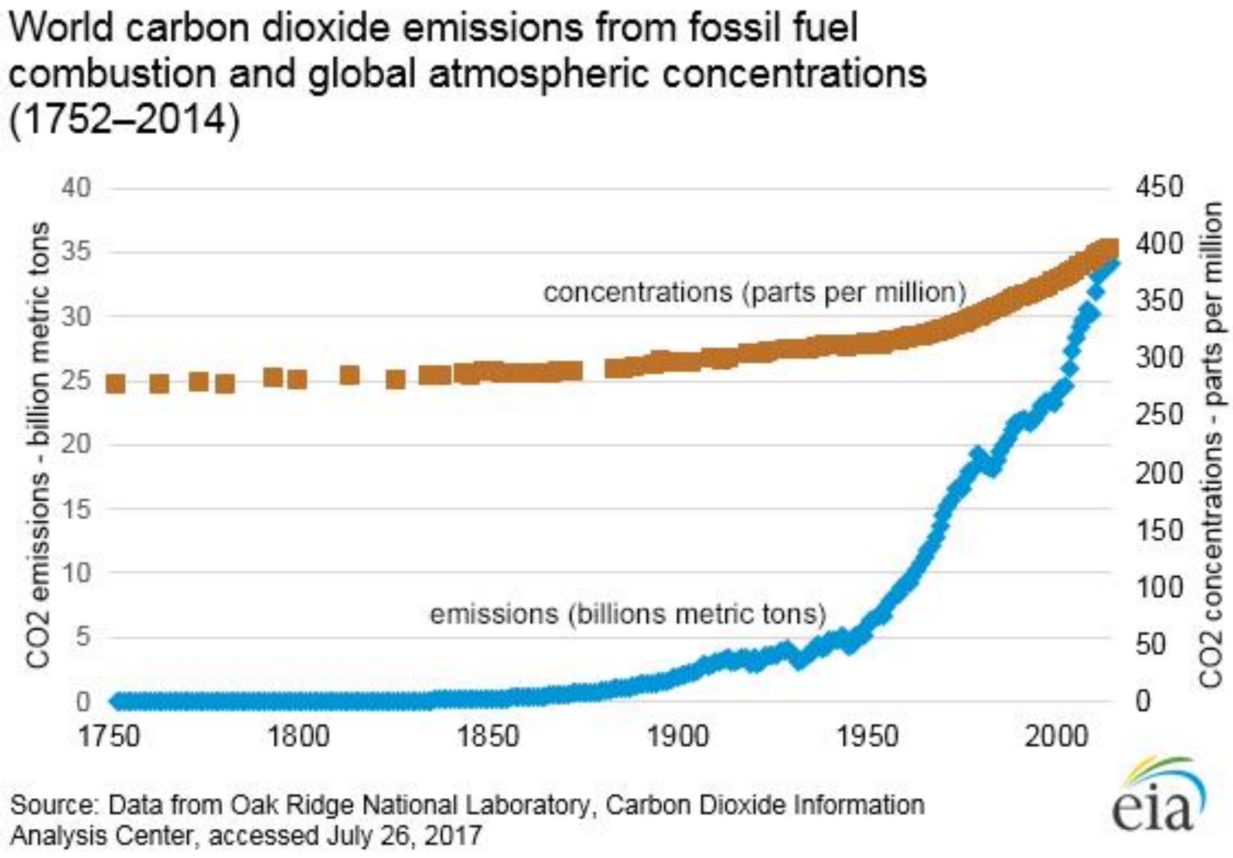
methane (CH_4)



nitrous oxide (N_2O)

Human activity increases Greenhouse gas concentration in the atmosphere

Shifts in the past atmospheric concentrations of CO_2 are linked to natural fluctuations (changes) in the climate, but it is now apparent that the predominant (main) factor in current climate change is human caused emissions of greenhouse gases.

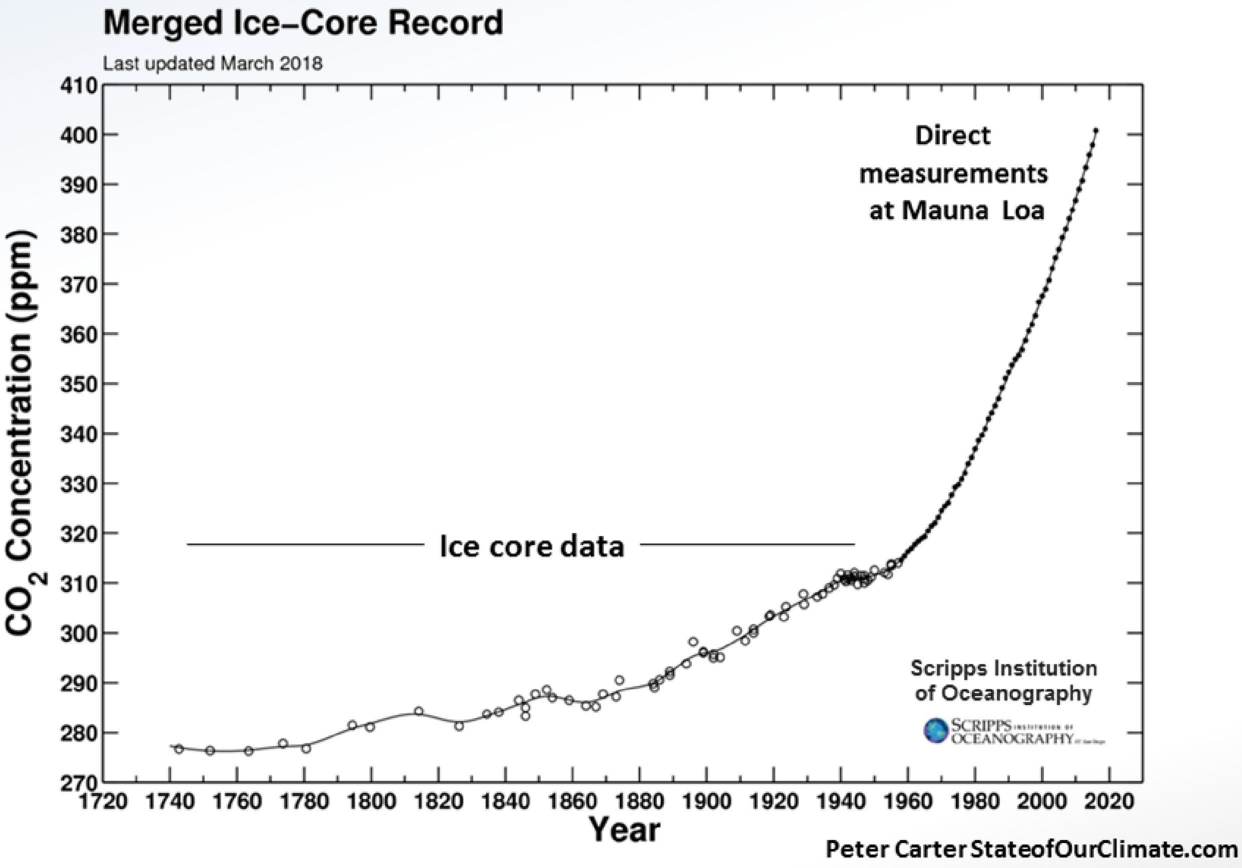


World carbon dioxide emissions from fossil fuel combustion and global atmospheric concentrations (1752–2014)

Source: Data from Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, accessed July 26, 2017

https://www.eia.gov/energyexplained/print.php?page=environment_how_ghg_affect_climate

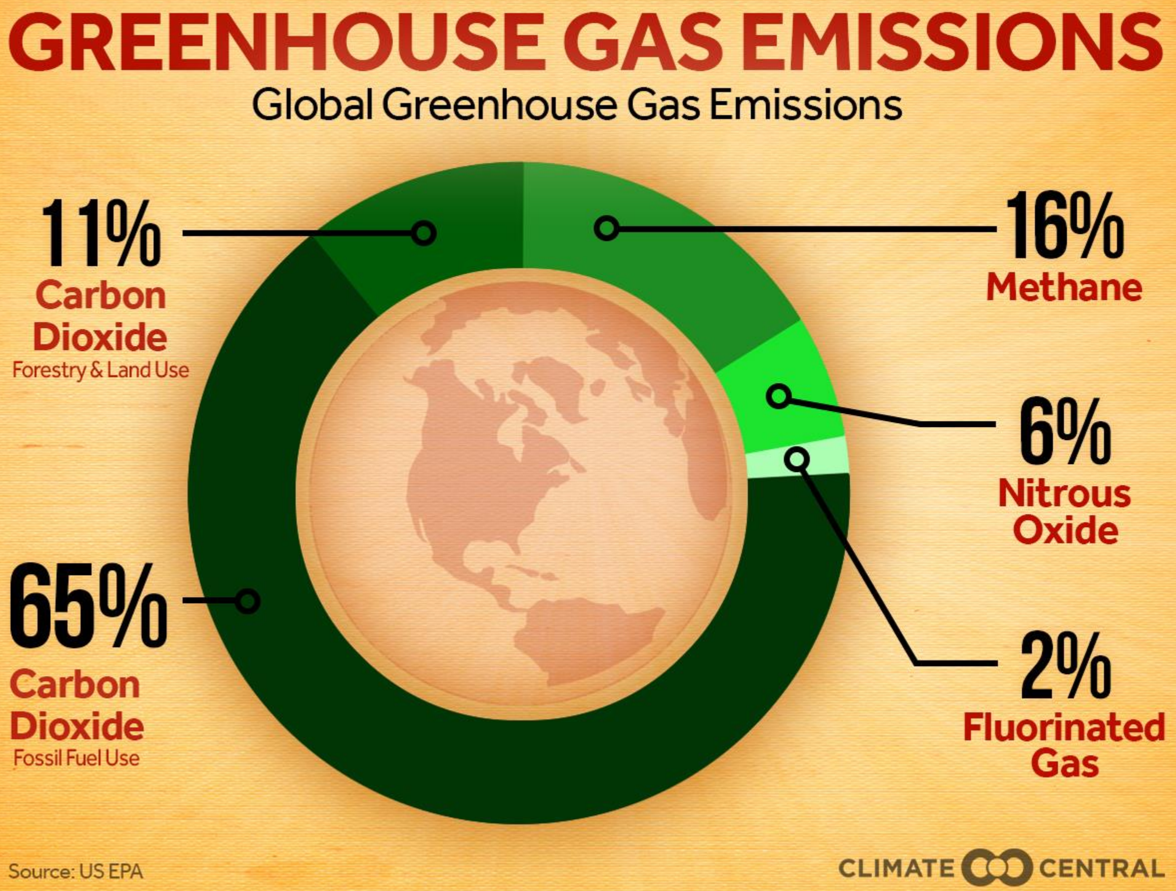
Increasing CO_2 concentrations in the atmosphere



Climate is powered by the solar radiation, and the Earth experiences natural fluctuations and cycles in its climate. Scientists use evidence, in the form of observations and models, to establish that human activity contributes to climate change. Reliable temperature and rainfall observations have been recorded since the end of the 19th century.

The *Keeling curve* represents readings of atmospheric CO_2 from the Mauna Loa Observatory in Hawaii, collected since 1958

Where are the greenhouse gas emissions coming from?



GREENHOUSE GAS EMISSIONS

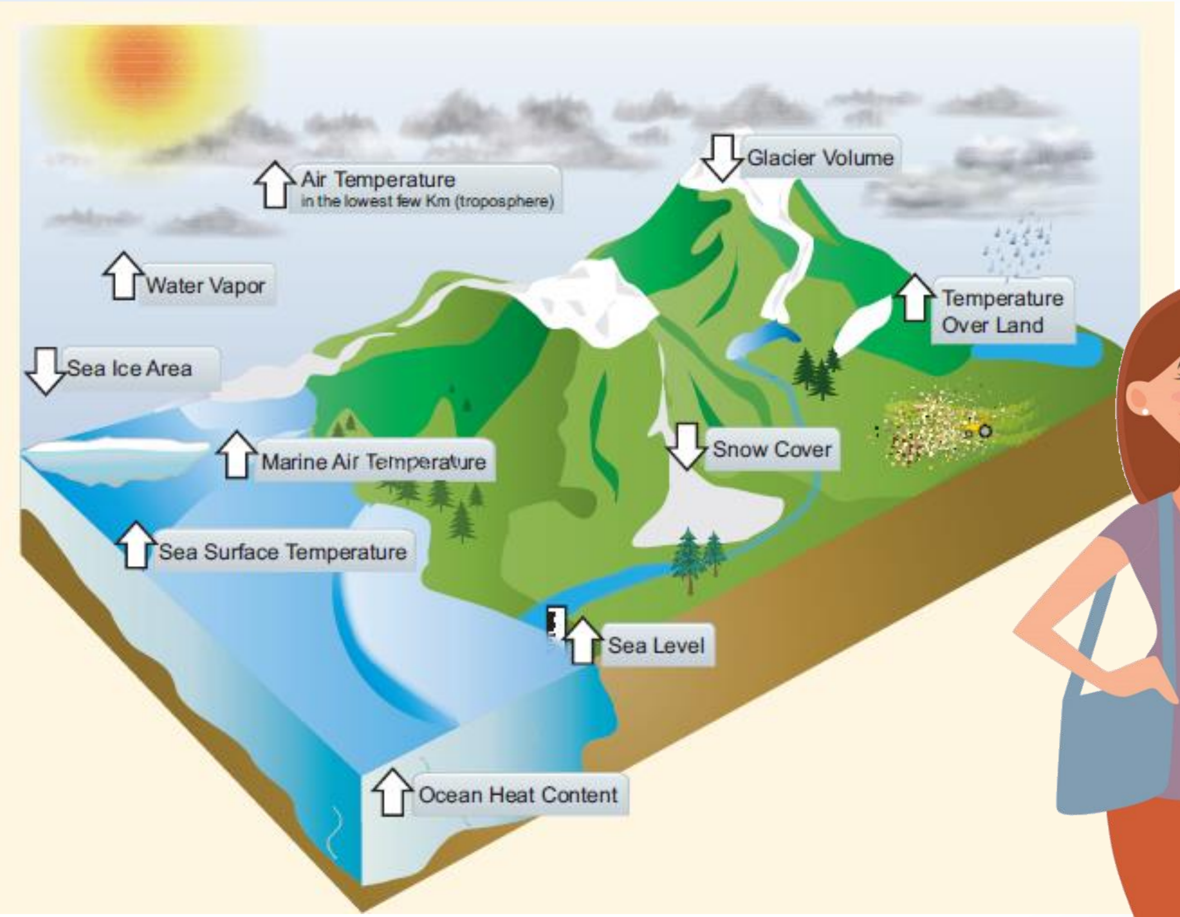
Global Greenhouse Gas Emissions

Source: US EPA

www.freepik.com

http://www.climatecentral.org/wmo-greenhouse-gas-bulletin-2015

Climate signals

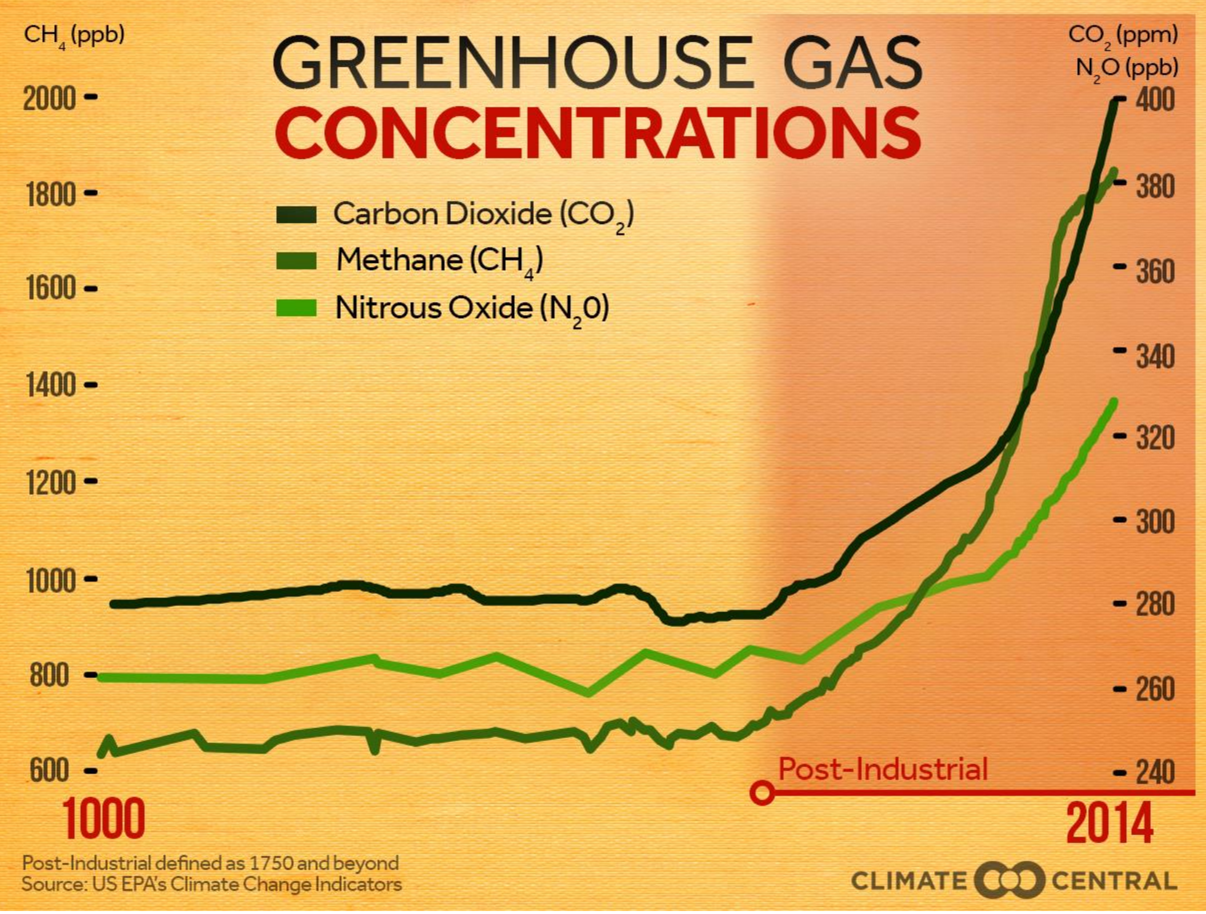


Features of the climate system (climate signals) affected by climate change. The arrows show the direction of change. (IPCC, 2013)

Climate Signals are long-term trends, including temperature, sea level, glaciation, and rainfall patterns, and allow us to tell if there has been any significant movement from naturally expected climate trends

http://www.climatecentral.org/wmo-greenhouse-gas-bulletin-2015

Comparing pre-industrial climate signals to post-industrial climate signals



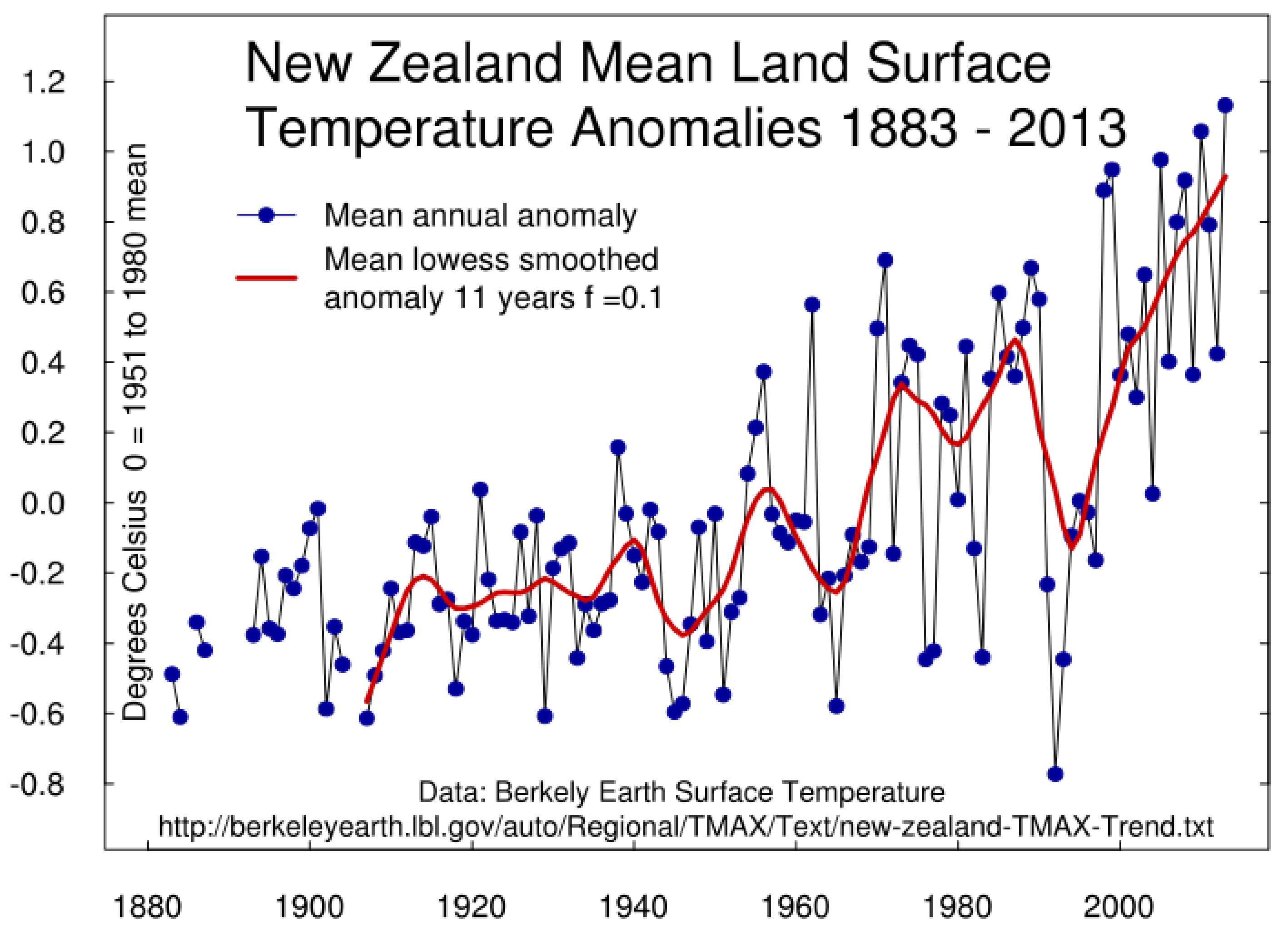
GREENHOUSE GAS CONCENTRATIONS

Post-Industrial defined as 1750 and beyond
Source: US EPA's Climate Change Indicators

www.freepik.com

Naturally fluctuating (moving) temperature and carbon dioxide signals, prior to human activity, can be compared to post-industrial signals. Using observations and projections, scientists can now state that it is "extremely likely", with a confidence of 95-100%, that Climate Change is due to anthropogenic (human) influence.

Temperature changes

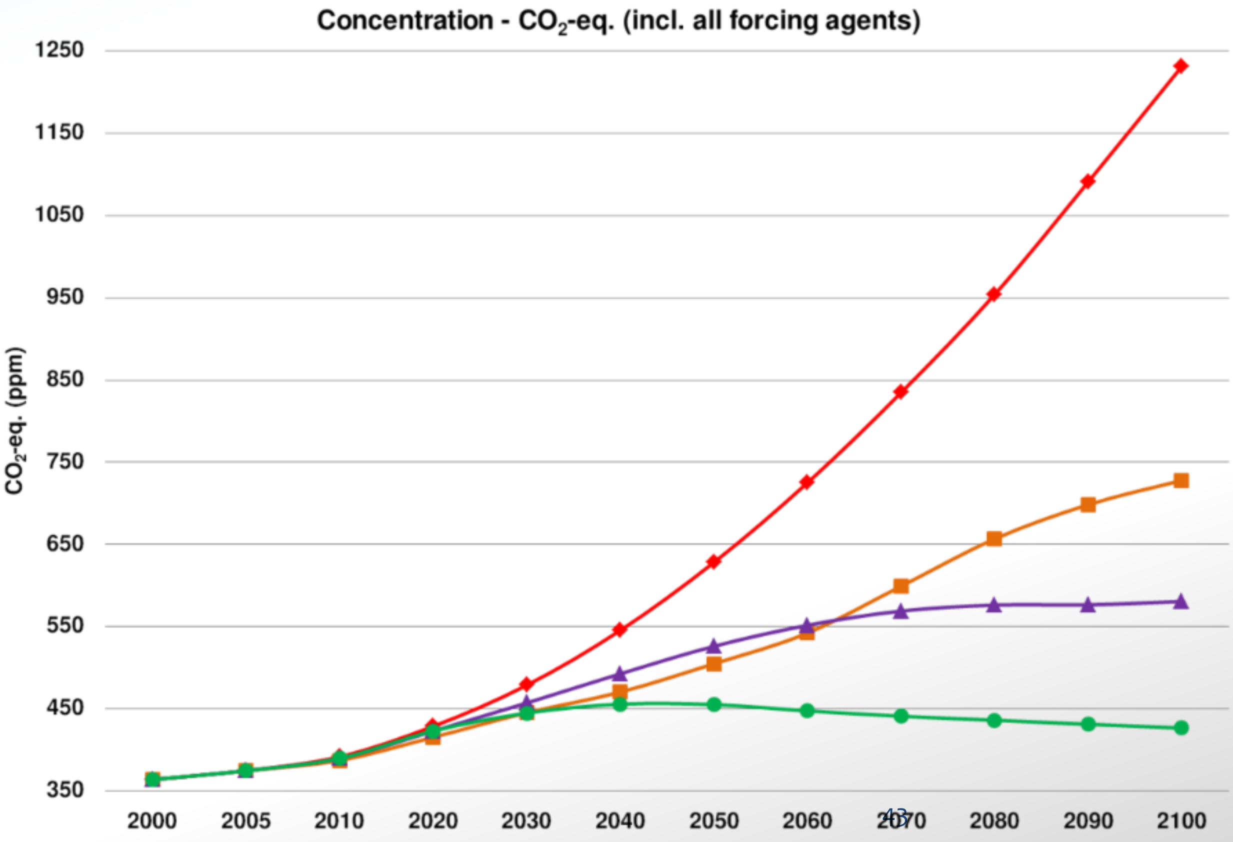


The past three decades have been hotter than all decades since temperature observations were recorded in the 19th Century, and the warmest has been the most recent decade.

Graph attributed to: Mrfebruary - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=46210465

How much CO_2 will humans produce in the future?

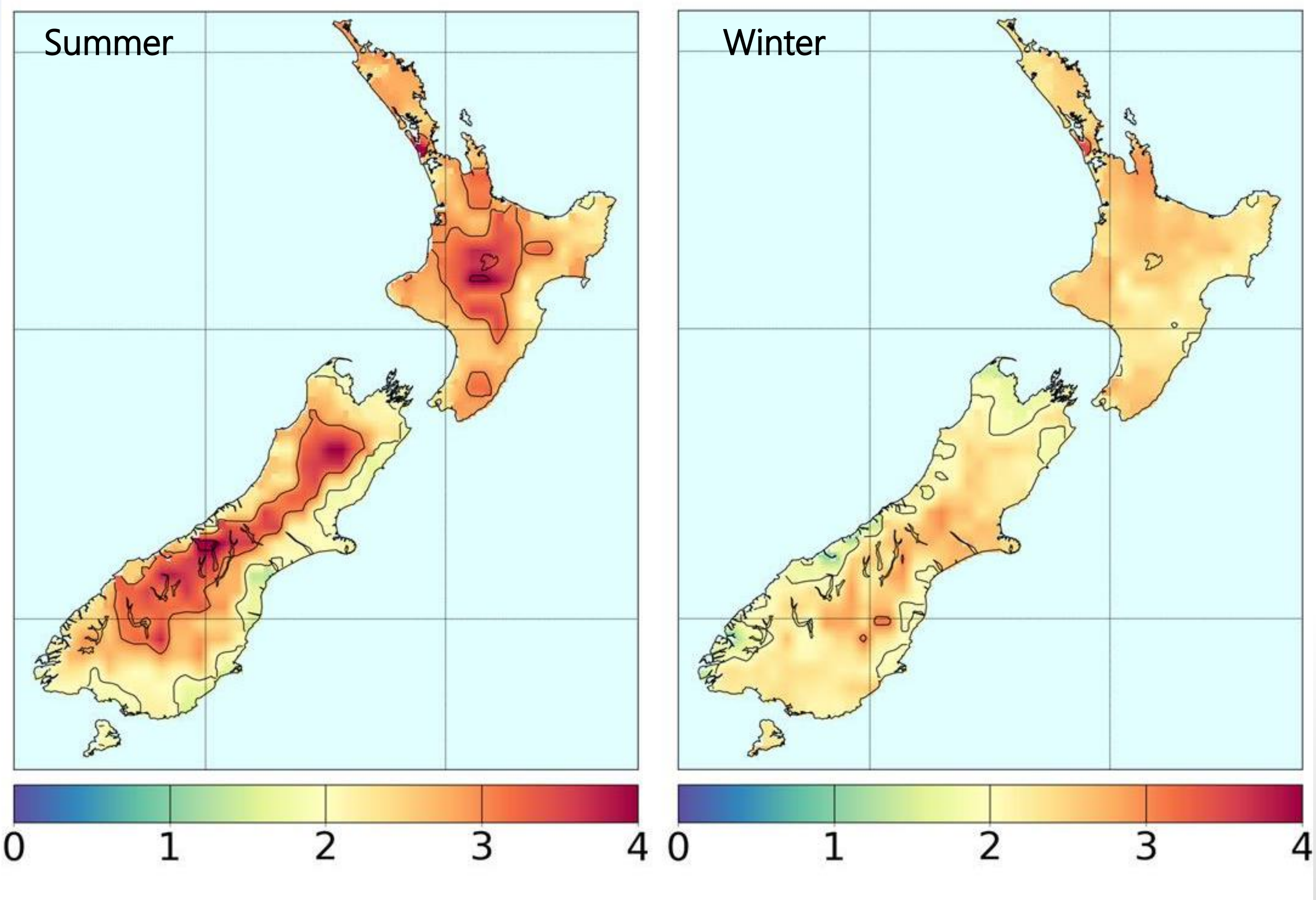
We can measure how much CO_2 we are producing at the moment, and releasing into the atmosphere. Predicting the future amounts of CO_2 becomes more difficult, as we look further into the future. By making big changes to how we live, and finding ways to remove current CO_2 in the atmosphere, we may be able to limit the projected rise of the earth to under 2°c. (green line).



At the other extreme, If we do nothing, and even increase the amount of CO_2 we release, the temperature rise (and sea level) could reach levels that completely change the Earth. (red line). It is more likely that we will end up somewhere between these two predictions.

Temperature rise predictions

Predicted increase in average temperature (°C) by 2090, relative to 1986-2005. (for highest CO_2 emissions prediction)



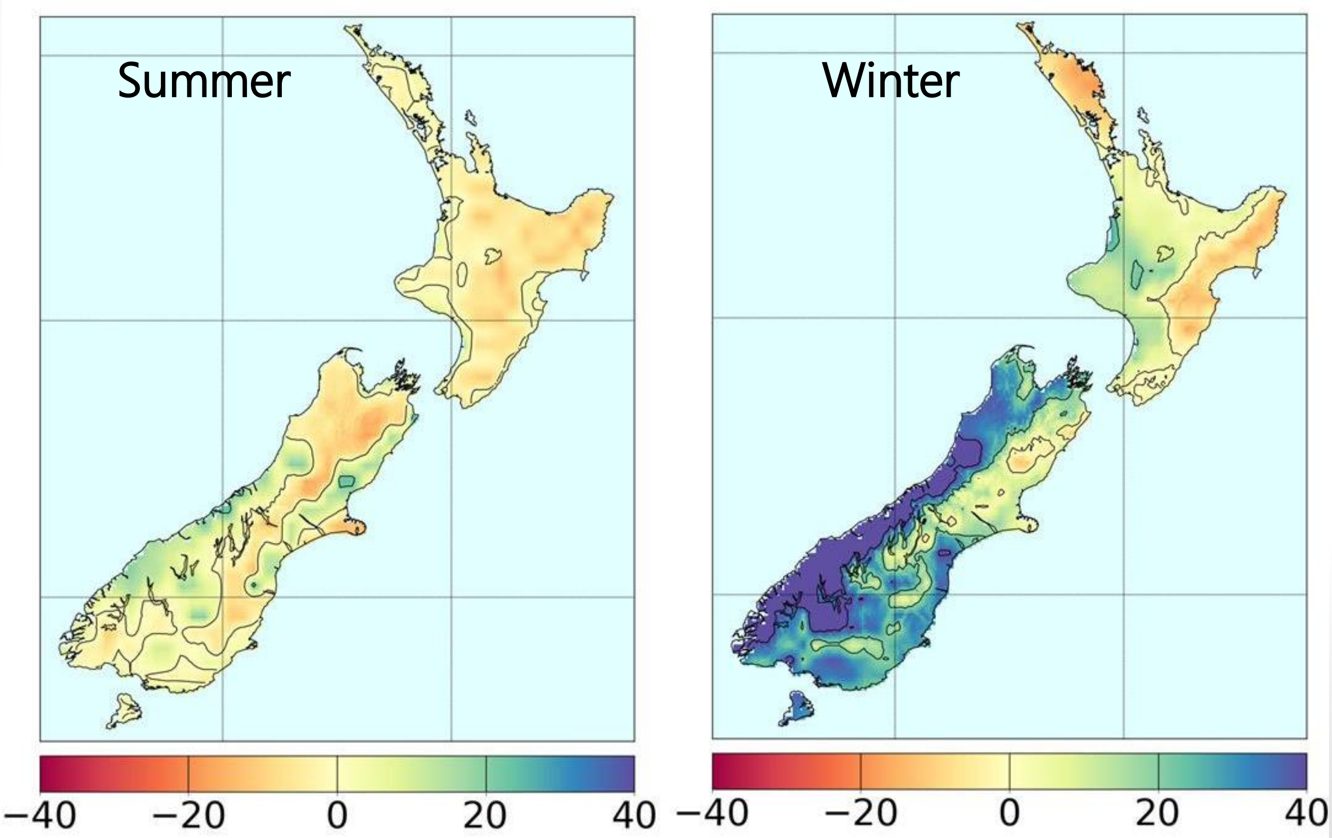
°C change from 1986-2005 average time period

Using climate models generated from the NIWA supercomputer, for **a medium CO_2 emissions scenario**, NZ may experience a temperature increase of 0.8°C by 2040, 1.4°C by 2090, and 1.6°C by 2110, relative to the 1986–2005 period" with a maximum of 5.0°C in 2110, using **the highest emission scenario.**

Graph attributed to: https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

Climate Change rainfall predictions

Predicted increase in precipitation (rainfall) (%) by 2090, relative to 1986-2005. (for highest CO_2 emissions prediction)



% change from 1986-2005 average time period

Changing rainfall patterns can also be predicted using CC models, and in NZ it is projected that the west of both Islands will become gradually wetter and the north and east will become drier in climate. In future, it is also predicted that NZ will have "more "hot days" and fewer frosts". Temperature and precipitation extremes have increased and become more frequent around the world.

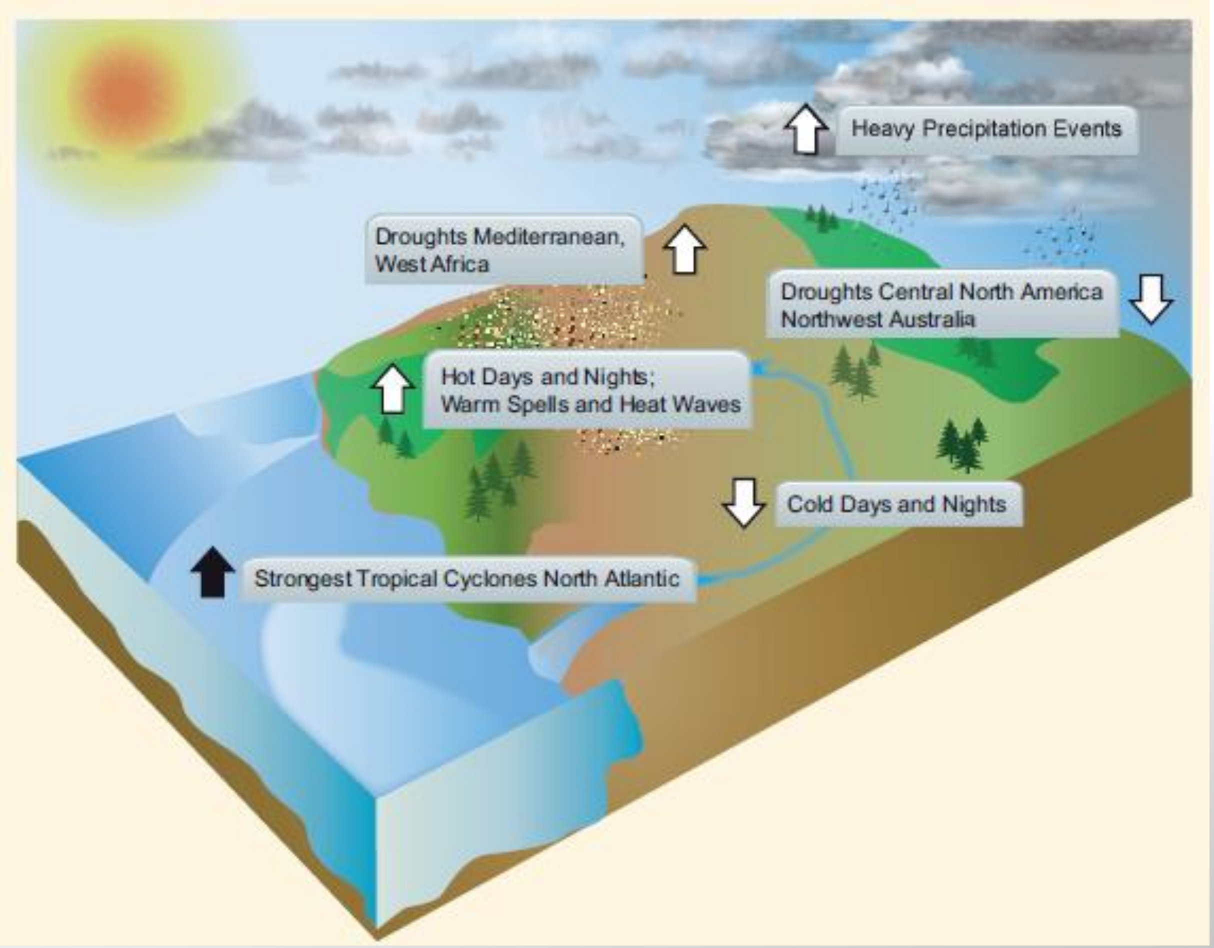
Sourced from: https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

Climate Change - Extreme Weather Events

Extreme weather events are stronger, and occur less often than typical weather.

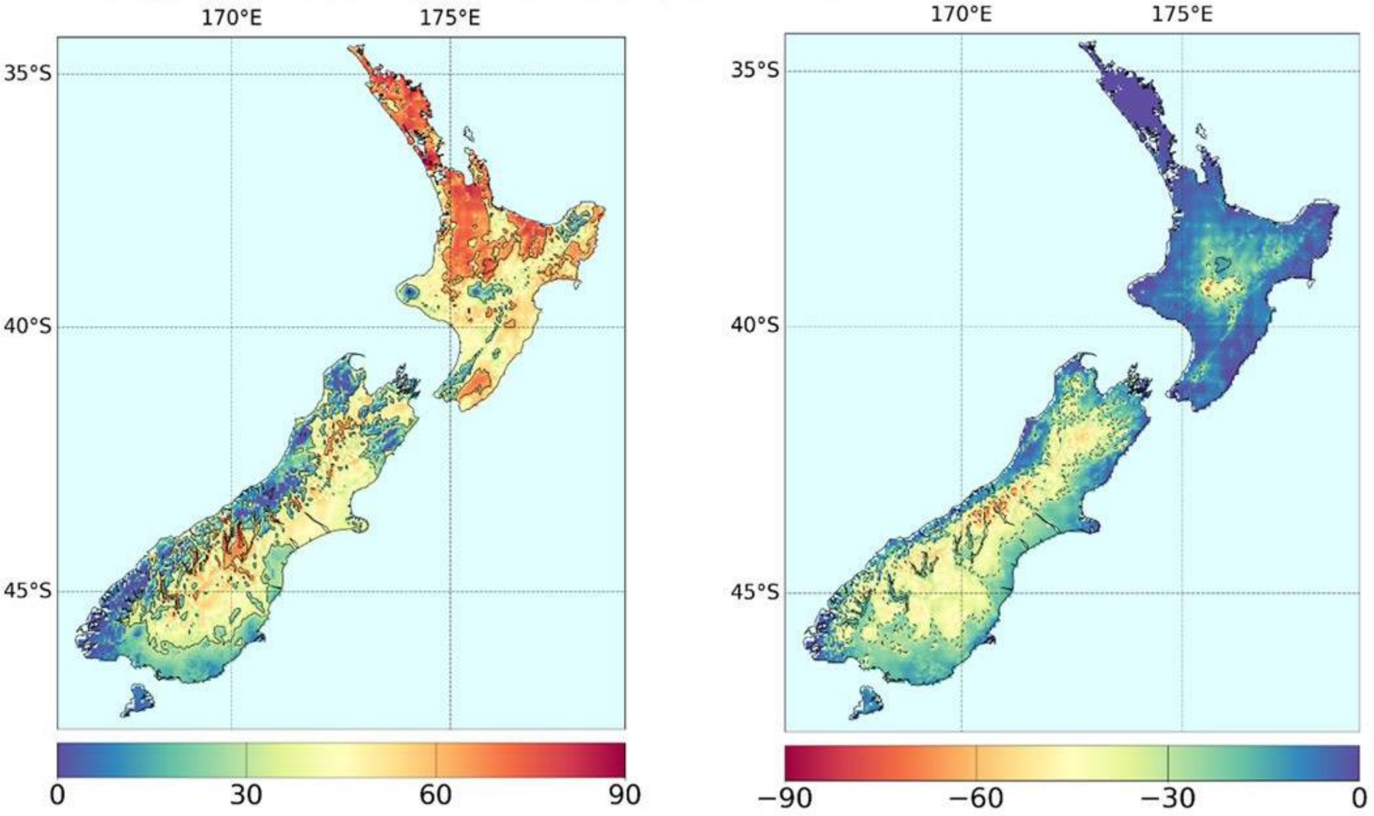
Extreme weather events are induced by both natural and human-activity causes.

These cause a shift in the balance of Earth's energy, which powers the climate system. Extreme weather events include droughts, storms, deluges, heat waves, and tornados, and have increased in frequency since the 1950's.



Climate Change - Extreme temperatures

Predicted change in number of extreme temperature days by 2090, relative to 1986-2005. (for highest CO_2 emissions prediction)



Days above 25°C

Days below 0°C

Number of days change from 1986-2005 average time period

Sourced from: https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

Extreme weather events in NZ are predicted to increase in frequency, and include both extreme rainfall events and drought across the country.

Melting of the Cryosphere and sea level rise

Multiple lines of evidence show that global warming, as a consequence of climate change, has caused the reduction of the *cryosphere*, consisting of sea and land ice, glaciers, and permafrost, in the past 30 years. Paleo (pre-history) records show that previous episodes of naturally induced global warming, around 2°C warmer than current temperatures, had produced a sea level rise (SLR) of more than 5m above present levels.

Change in Fox Glacier, West Coast, New Zealand from 2008 to 2014

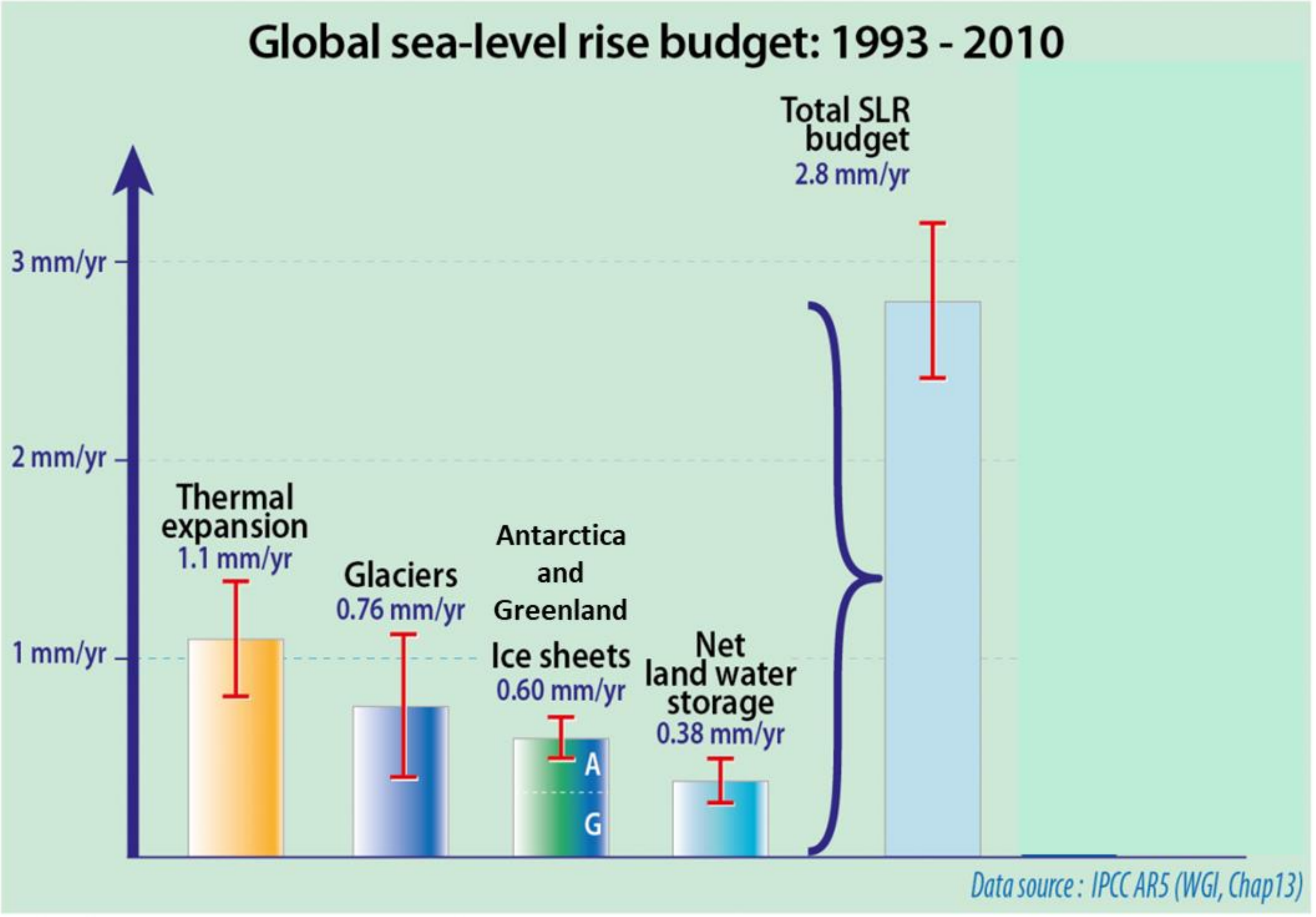
Sourced from: http://glacierhub.org/2016/07/26/as-glaciers-melt-tourists-keep-on-coming-in-new-zealand/

Change in Franz Joseph Glacier, West Coast, New Zealand from 2009 to 2013

Sourced from: http://glacierhub.org/2016/07/26/as-glaciers-melt-tourists-keep-on-coming-in-new-zealand/

Disappearing ice.

Observations now show that the Arctic sea ice is becoming thinner and smaller with each passing year. Continued warming of the planet could cause some large ice sheets, such as Greenland, to totally disappear, adding nearly 7m to long-term sea level rise.

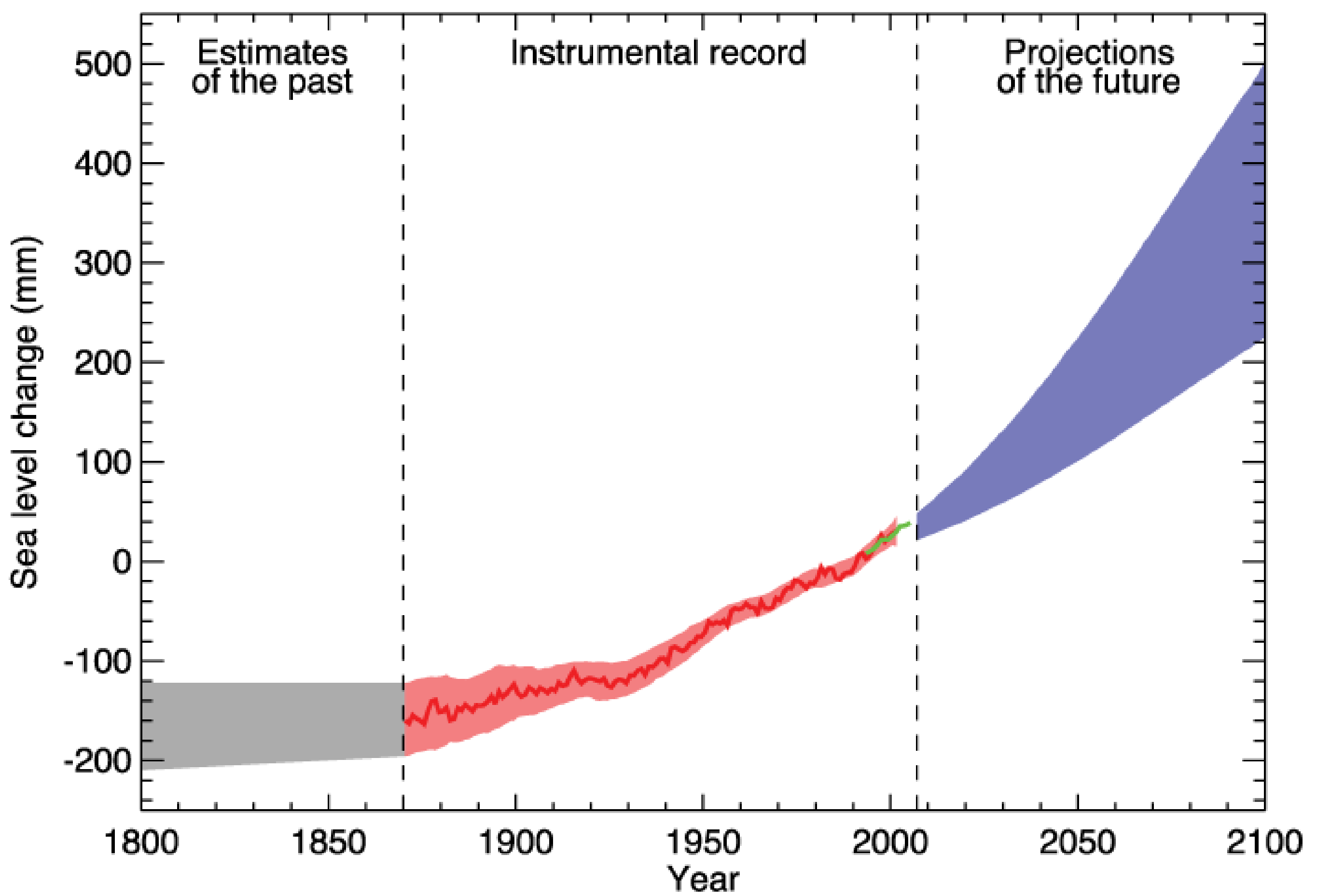


Data source: IPCC AR5 (WGI, Chap13)

The main contributors (75%) to sea level rise have been the melting of glaciers, predicted to continue shrinking even if the temperature stabilises and more recently the Antarctic and Greenland ice sheets. Calving glaciers make up 90% of the continental ice loss.

Sea level rise predictions

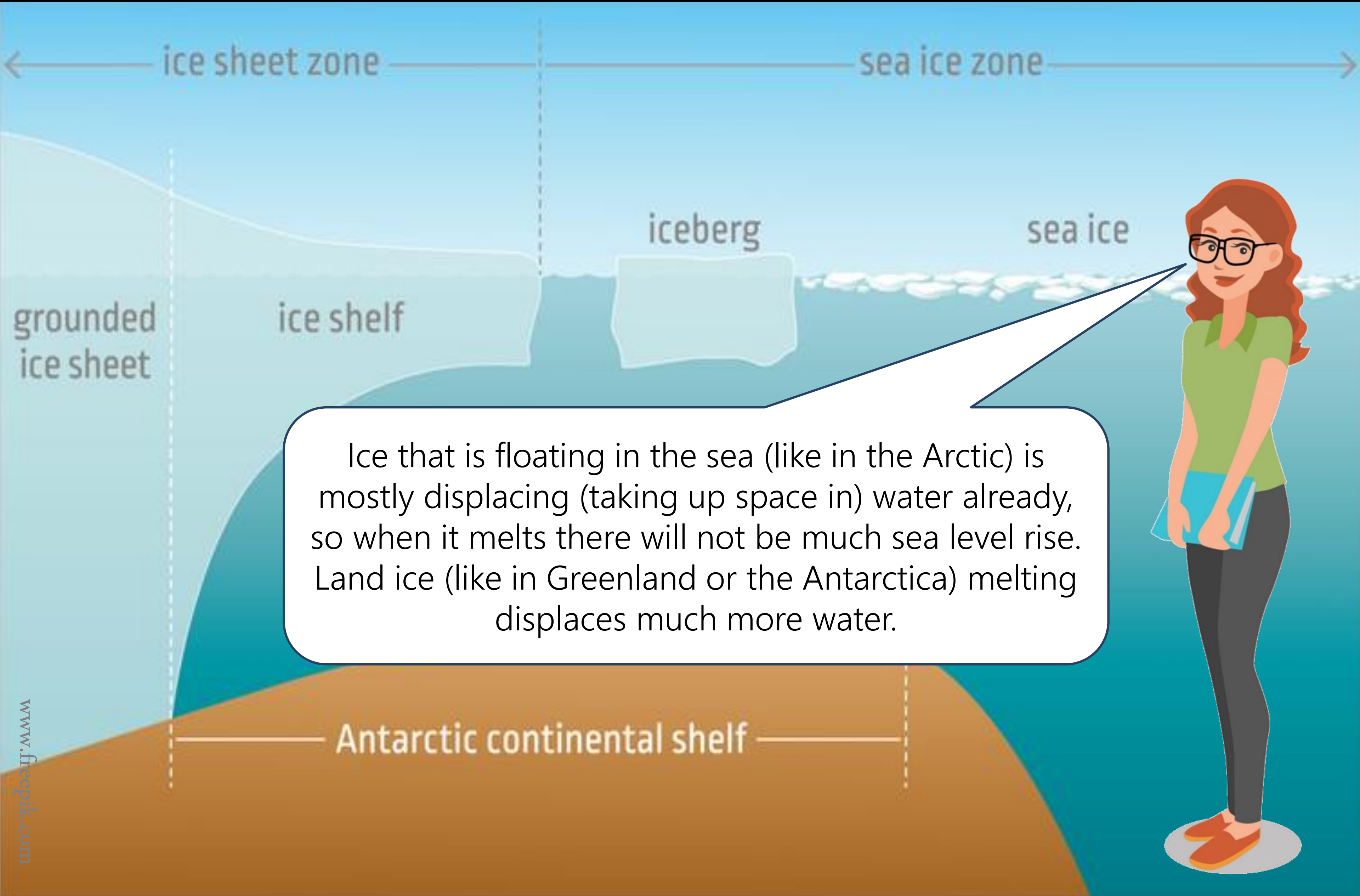
Predicted ranges for sea level rise by 2100 are from 0.26 to 0.98 m, depending upon future emission levels. In the last decade the rate of sea level rise is double that compared to the previous century, with small islands most exposed to risk.



Sourced from: http://thebritishgeographer.weebly.com/sea-level-change.html

NZ is particularly susceptible to sea level rise, due to the long coastline, and the position of many communities, and major cities, in low-lying areas near to the coast. The rising sea levels will cause coastal land erosion and flooding, and result in reduced land area.

Why does only land ice contribute to sea level rise (and not sea ice)?

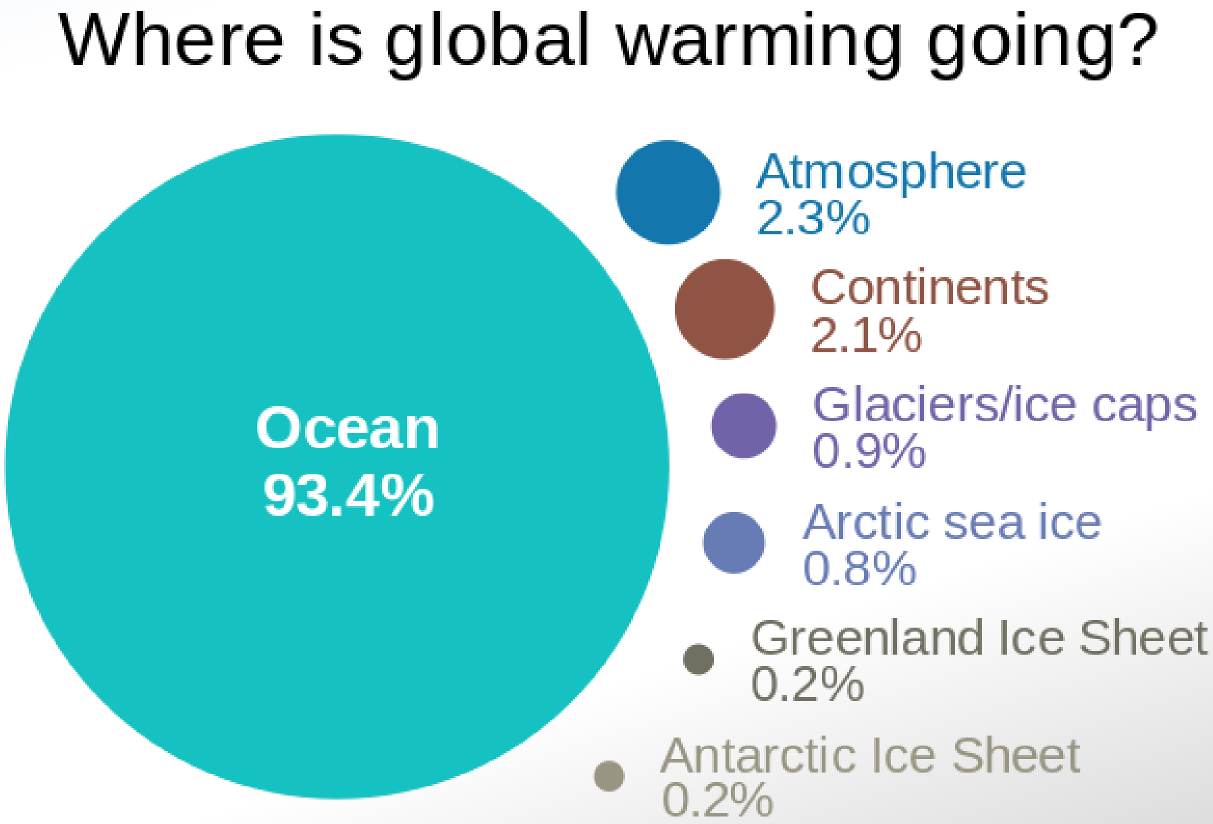


Ice that is floating in the sea (like in the Arctic) is mostly displacing (taking up space in) water already, so when it melts there will not be much sea level rise. Land ice (like in Greenland or the Antarctica) melting displaces much more water.

www.freepik.com

Heating Oceans

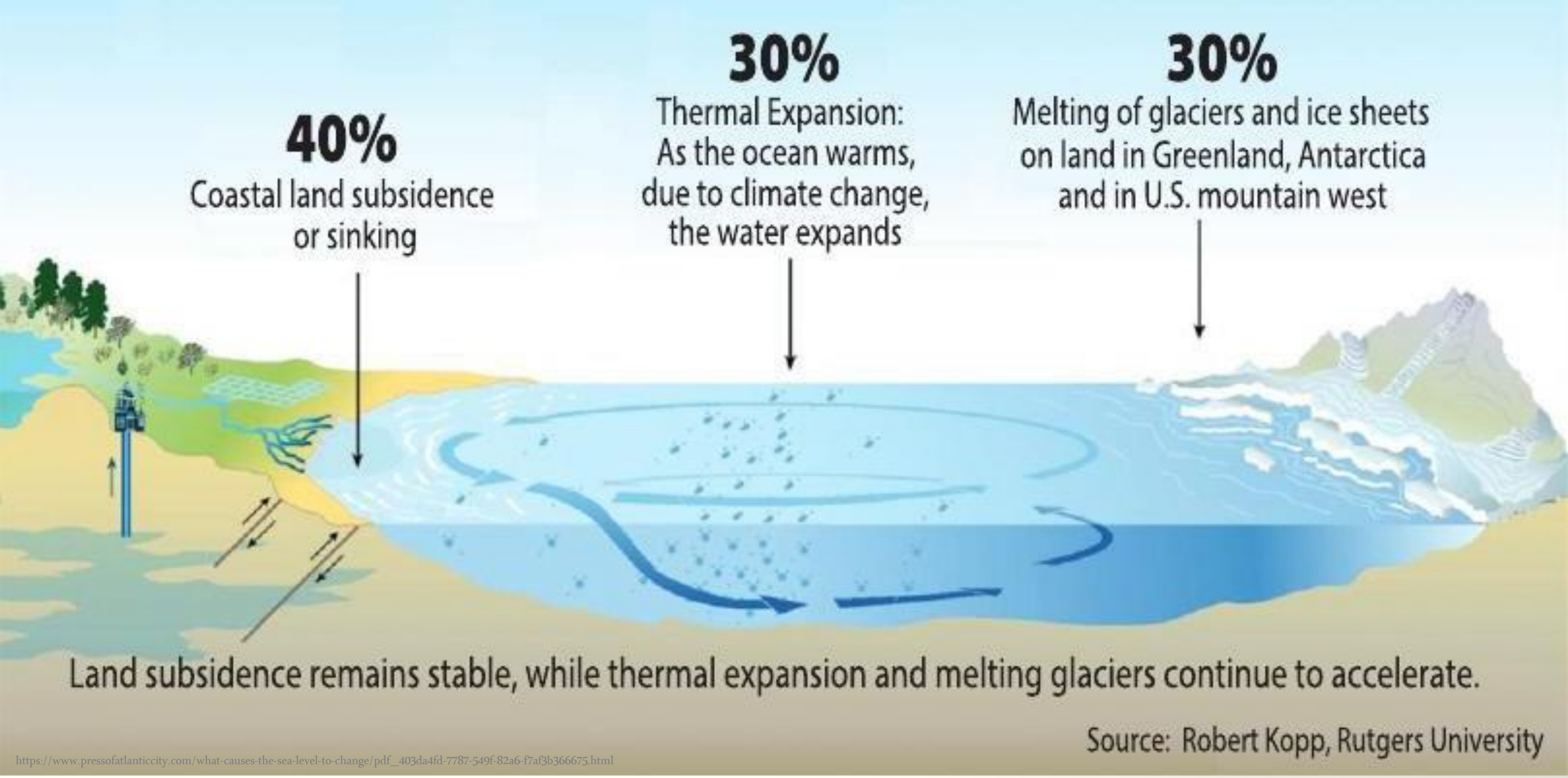
Most of the extra heat created by the additional greenhouse gases is being absorbed by the oceans. The oceans are huge so they are taking a long time to heat, but the extra warmth is causing problems for the living things that call it home, and changing the water moves around.



https://www.skepticalscience.com/Ocean-Heat-Content-And-The-Importance-Of-The-Deep-Ocean.html

www.freepik.com

What else causes the sea level to rise?



Land subsidence remains stable, while thermal expansion and melting glaciers continue to accelerate.

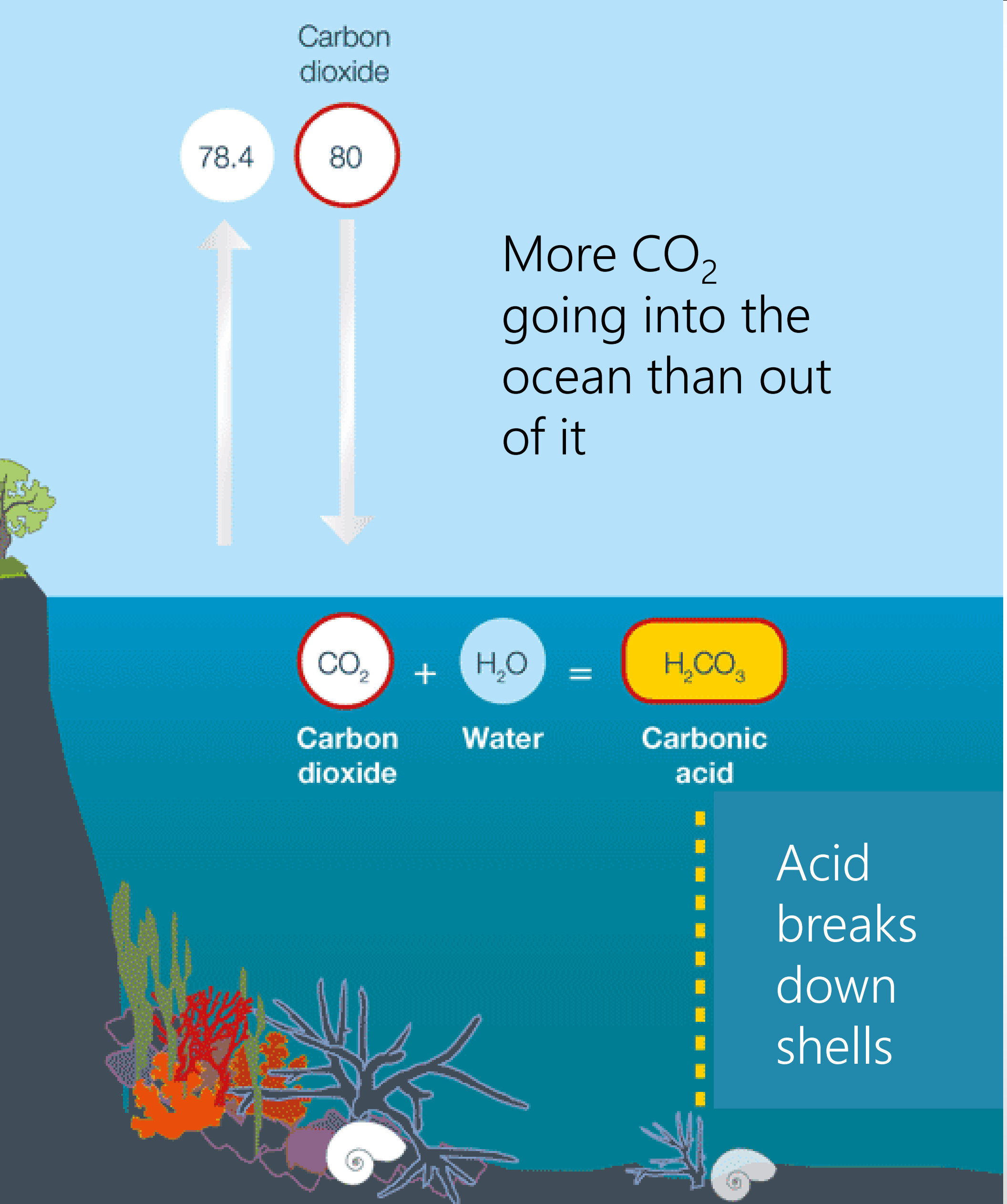
Source: Robert Kopp, Rutgers University

https://www.pressofatlanticcity.com/what-causes-the-sea-level-to-change/pdf_403da4fd-7787-549f-82a6-f7af3b366675.html

Thermal expansion from heating oceans also contributes to sea level rise, as the average temperature of the ocean risen 0.17°C in the past 40 years. The ocean water has a high capacity to absorb energy and, therefore, shows a slower increase in temperature than on land.

https://coastadapt.com.au/ocean-acidification-and-its-effects

Ocean Acidification



More CO_2 going into the ocean than out of it

Acid breaks down shells

CO_2, from human activity, is being dissolved into the ocean carbon sinks, causing *ocean acidification*. The ***pH*** (measure of acid) of the water is becoming more acid.

Acidification is harmful to many marine organisms, as most function optimally (the best) within a narrow range of pH. Many marine organisms, including shellfish and corals, have shells made of a compound called carbonate. The shells are being *neutralised* (a chemical reaction) by acid, which **creates weak or breaking shells.**

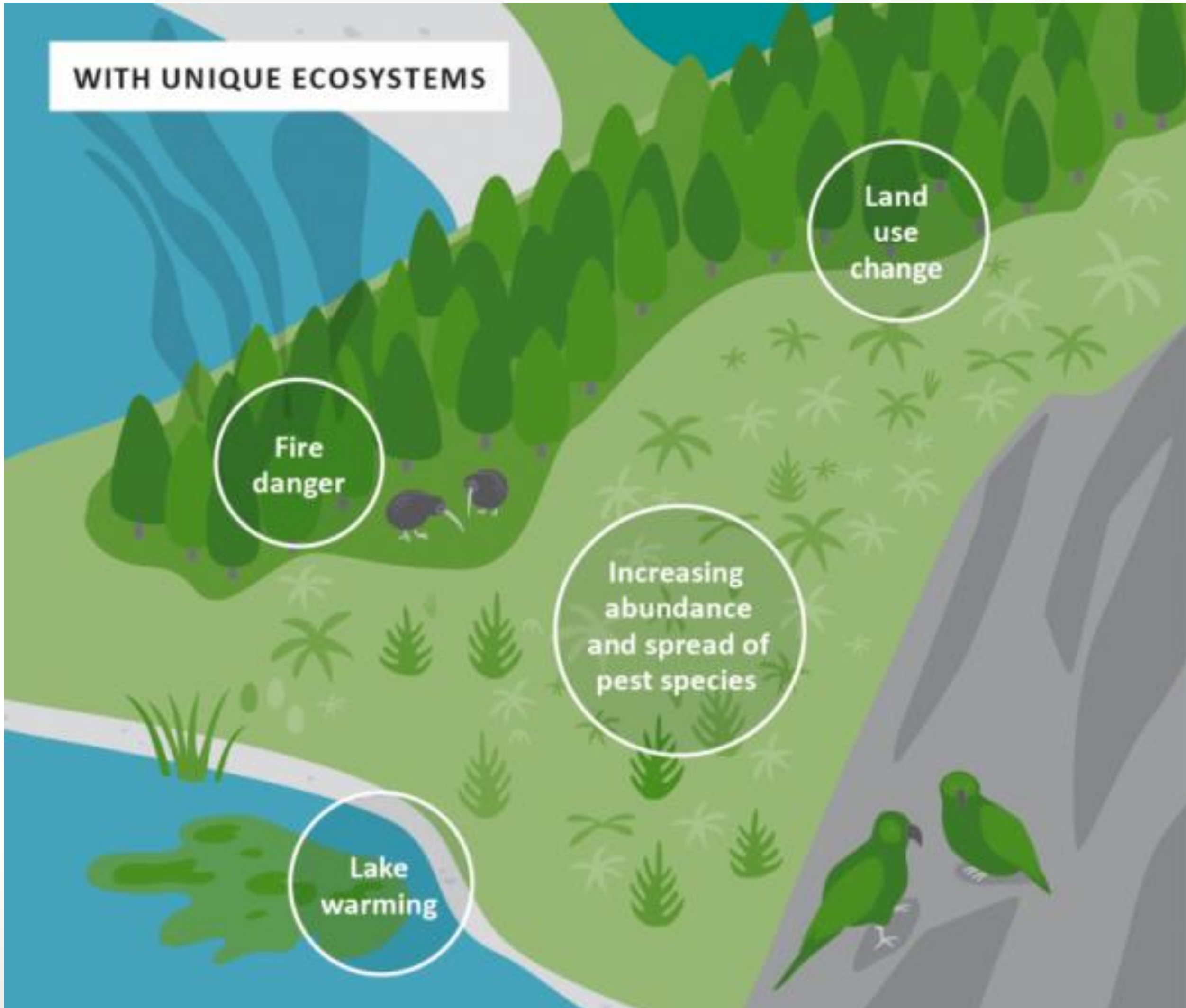
Climate change effects ecosystems

New Zealand, like the rest of the world, is likely to experience climate shifts, and many endemic (that are not found anywhere else) species, already under threat, may face extinction, as they are unable to adapt to the rapid changes in their habitats.

In NZ, we are likely to see ecosystem damage, habitat shifts for plant and animal species, and an earlier start of spring plant growth, migration, and mating events.

Pest species may travel into new areas and threaten our endemic species.

Human populations may have to move into areas that endemic species live.



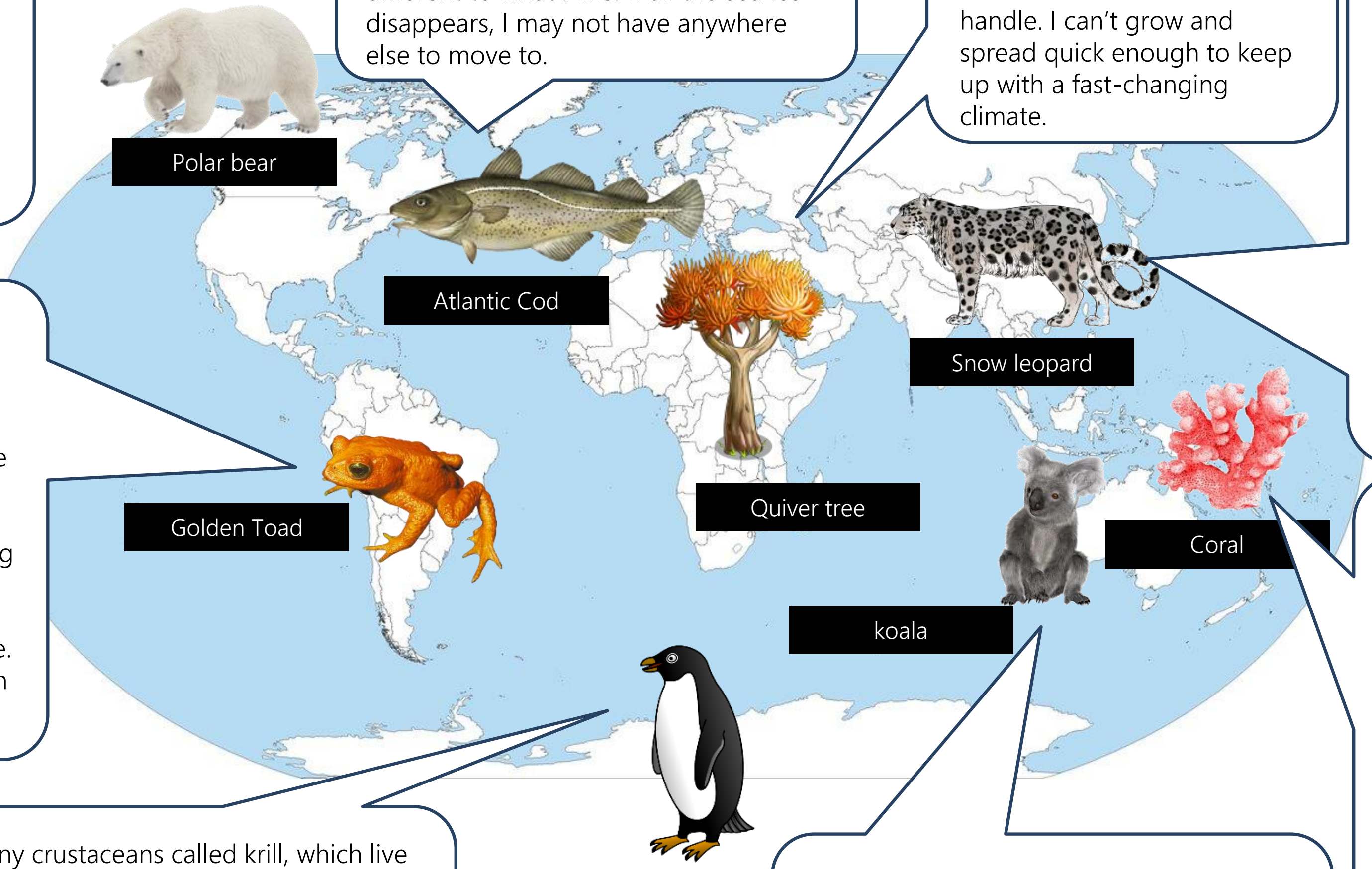
Our World is changing

I need ice sea, so I can sneak up and hunt for seals in spring and summer, when my young are coming out into the world for the first time. I can't swim fast enough to catch the seals in the water, and I am going hungry.

I have to move to a new place to live, so I can find cooler areas to eat and breed. But when I move the food around me is different to what I like. If all the sea ice disappears, I may not have anywhere else to move to.

I can grow in dry and hot conditions, but climate change is making my home drier and hotter than I can handle. I can't grow and spread quick enough to keep up with a fast-changing climate.

I am quite rare already, and I have adapted to live in mountain areas away from humans. Climate change is causing humans to spread out into my home area, looking for new places to live. If I am chased away too many times I may have no where else to live.



I lived in misty mountaintop cloud forests. Climate change has increased the amount of droughts around my home, making it too dry for me, and I have no where else to live. Nobody has seen me for over

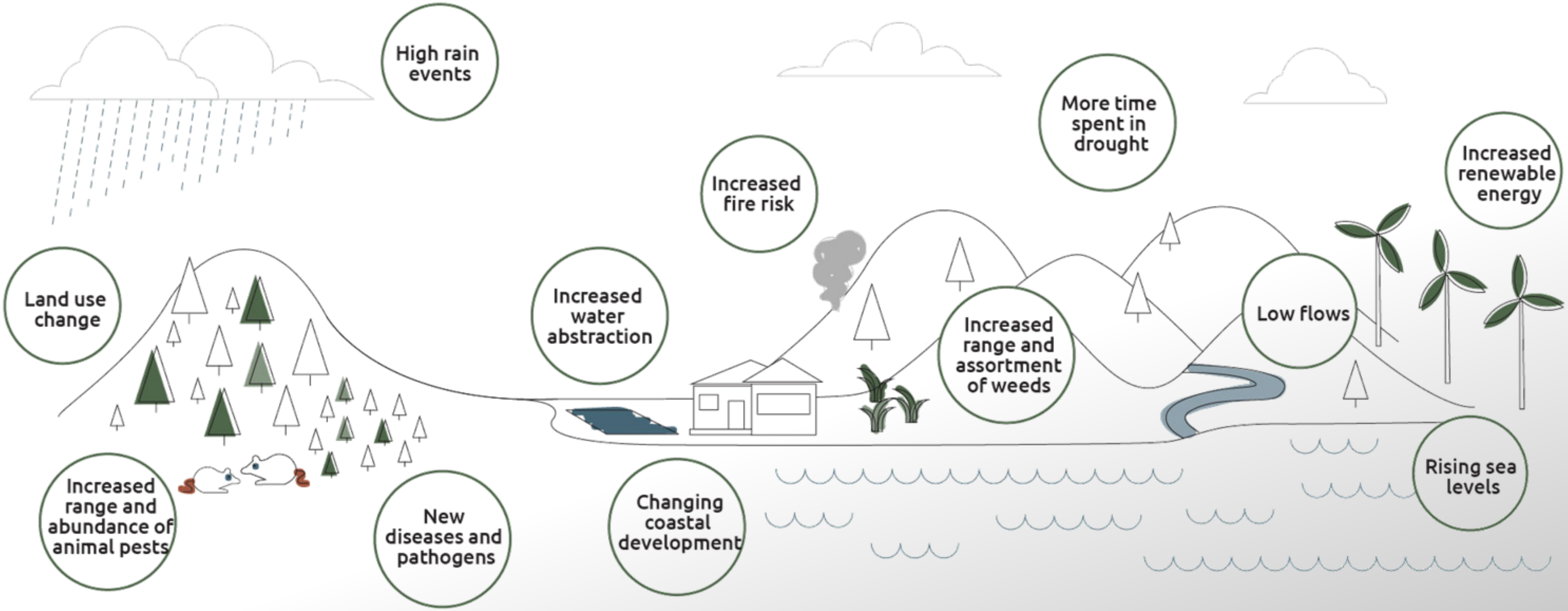
I eat tiny crustaceans called krill, which live on the undersides of Antarctic ice sheets. The ice sheets are melting, and I have to go further and further to find food. I now have less energy to raise my young.
30 years.

I have a very special diet and only eat one type of food. My food grows in dry places , but if climate change causes my home to be even drier it may not continue to grow here. I will need human help to move around and find more food.

I am very important to my ecosystem, and many other species rely on me for homes and protection. The algae, which lives inside me, and gives me a lovely colour, does not like any increase in temperature, so the warmer water is causing the algae to leave me!! I am starting to turn white.
30 years.

Climate change effects human communities

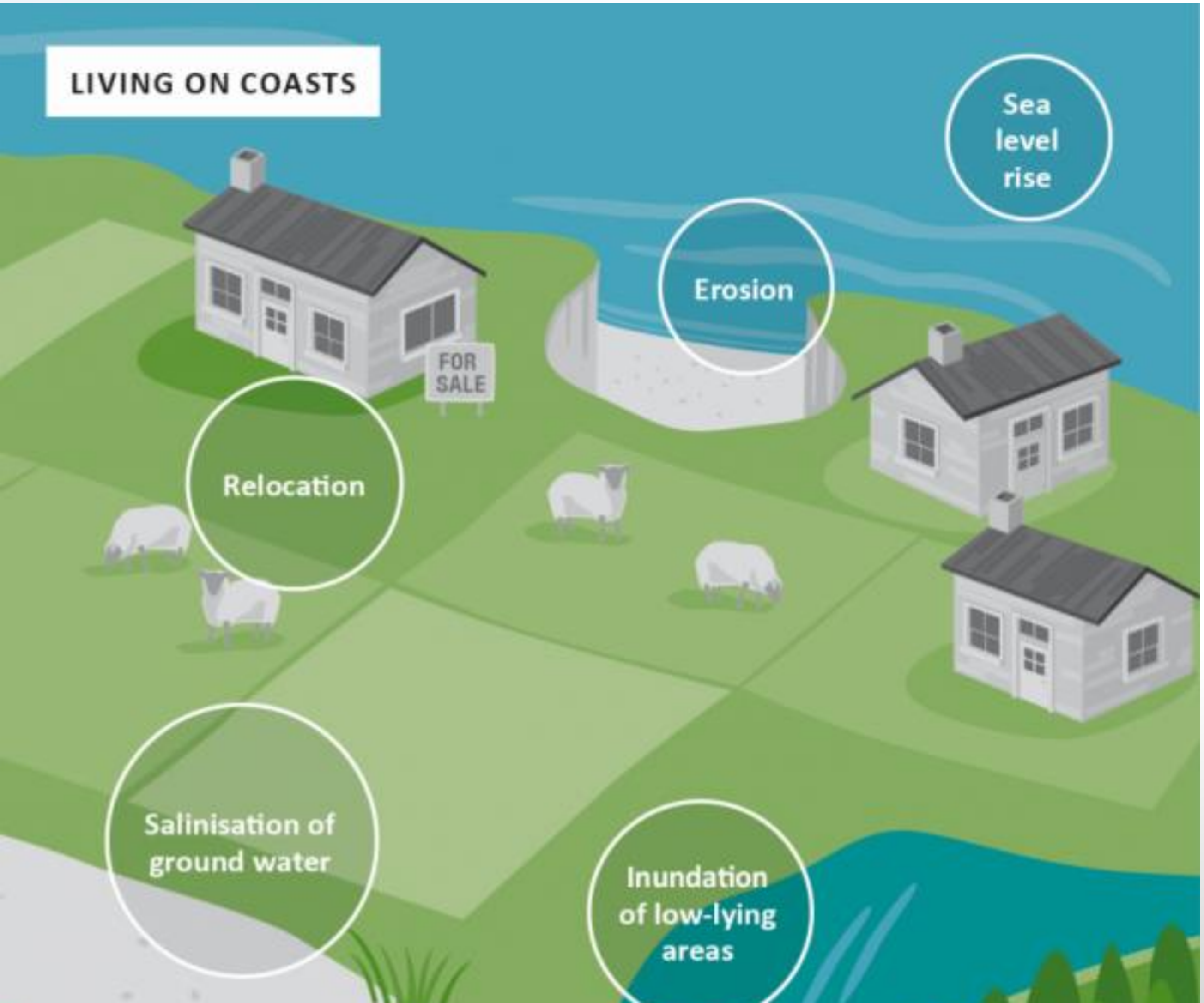
Climate change will affect the way we produce our food, manage our land and water resources, as well as have an impact on the infrastructure (buildings and structures built for our use) that we rely on in our rural and urban communities.



https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/auckland-plan/environment-cultural-heritage/Pages/climate-change.aspx

Climate change effects human communities

New Zealand is an Island, and many of our human communities are close to the coast. Those communities are likely to experience multiple effects due to climate change.



Some communities may have to relocate further away from the coast. Barriers may have to be built to kept the water away from the towns. Farms may have to move away from areas no longer suitable to grow food, and we may have to change the ways that we farm.

Climate Change Adaptation Strategies

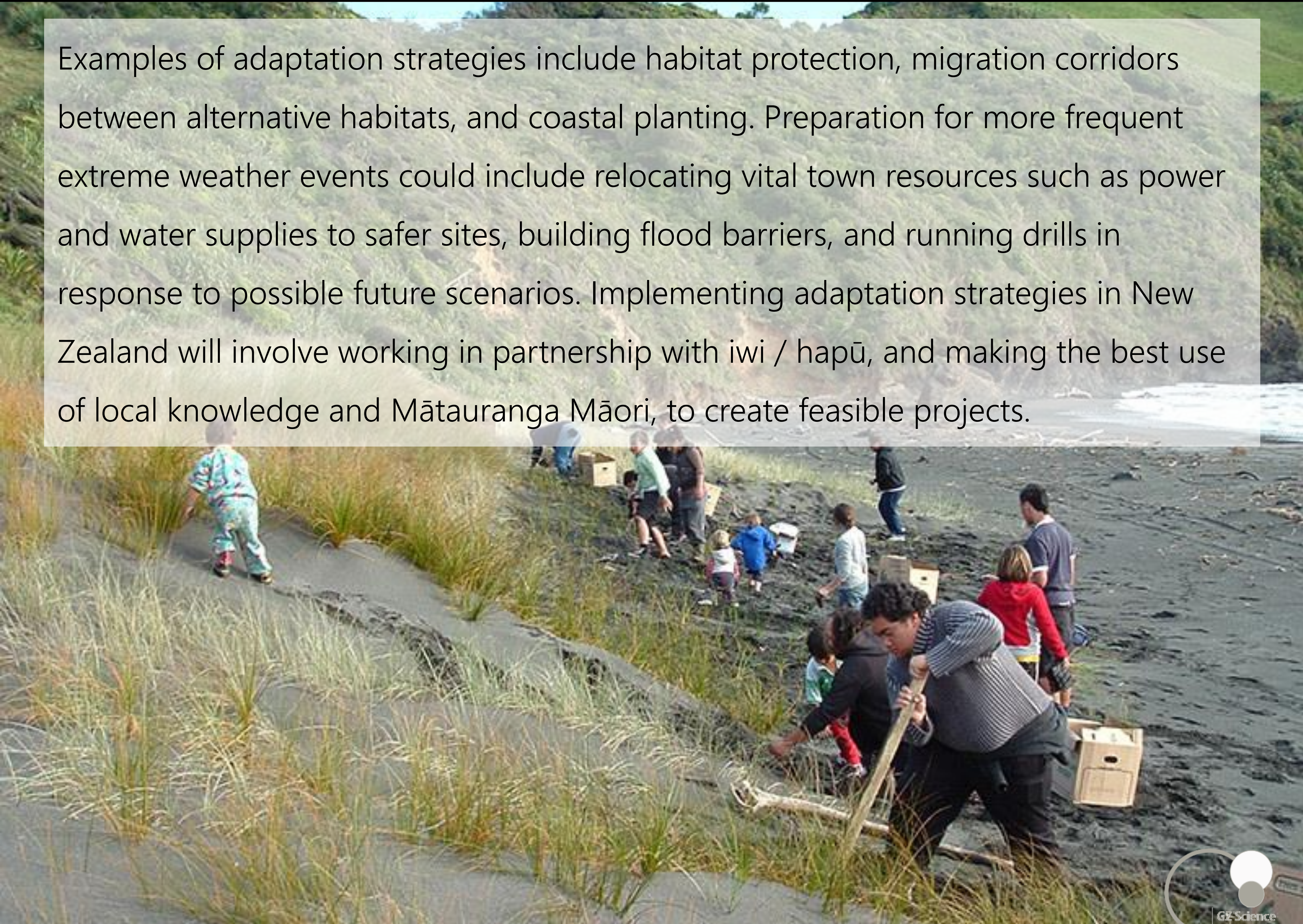
Adaptation helps us respond to future problems created by climate change. Every area, and population will face different changes in temperature, rainfall, sea level rise, and other factors. By starting projects to help solve immediate problems, and making plans for possible future predicted issues before they arise, we can help humans and other living things cope better with the changes.

New Zealand has already begun planning for adaptation, that will help us avoid, live with, move away from, and protect against climate change impact.

http://vector4free.com/vector/free-hills-landscape-vector/

www.freepik.com

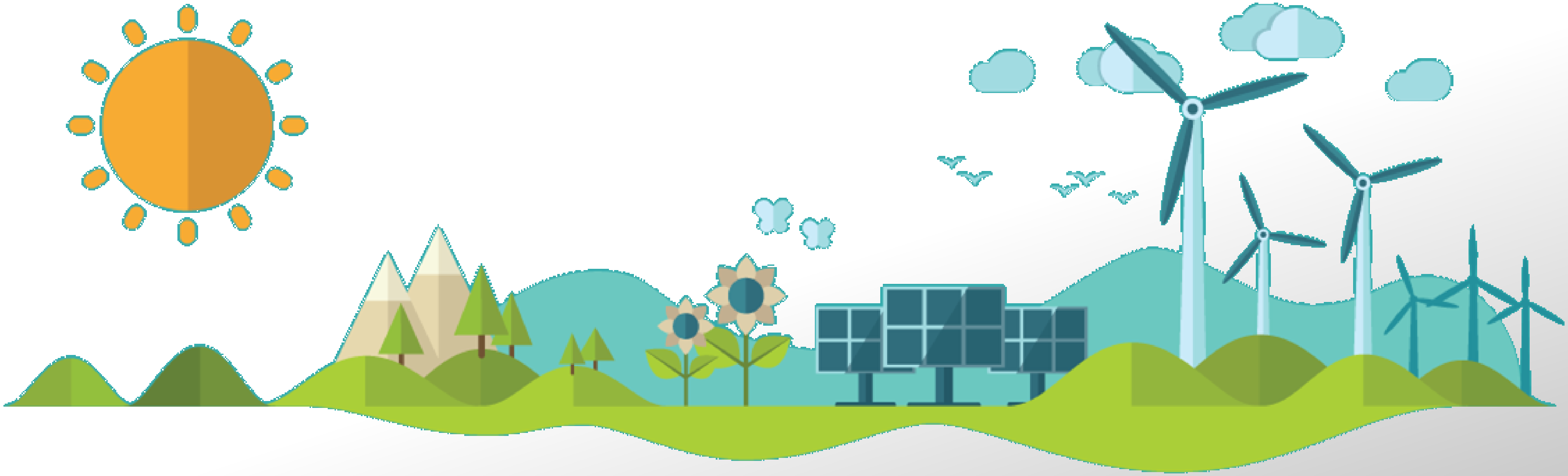
Climate Change Adaptation Strategies



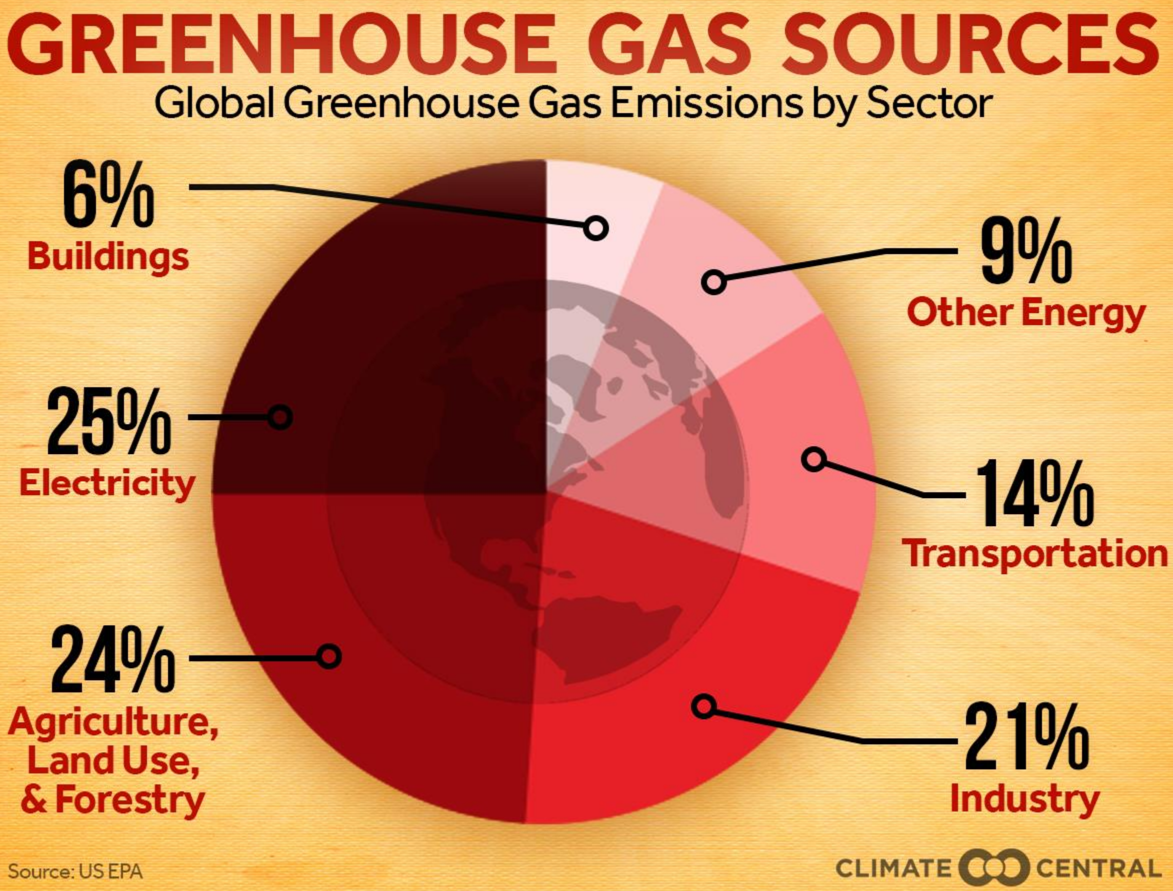
Examples of adaptation strategies include habitat protection, migration corridors between alternative habitats, and coastal planting. Preparation for more frequent extreme weather events could include relocating vital town resources such as power and water supplies to safer sites, building flood barriers, and running drills in response to possible future scenarios. Implementing adaptation strategies in New Zealand will involve working in partnership with iwi / hapū, and making the best use of local knowledge and Mātauranga Māori, to create feasible projects.

Climate Change Mitigation

Adaptation can help us adjust better to the negative consequences of climate change, but does not prevent the underlying reasons why climate change is occurring. *Mitigation* focuses on limiting or controlling the factors contributing to climate change. Mitigation projects can be started by countries, businesses, and individuals. These actions can reduce or prevent carbon dioxide emissions, the main cause of climate change, and this can include limiting energy use, developing alternative low carbon fuel, or sequestering (storing away) CO_2, either natural methods or designing new technology.



Who produces the CO_2 anyway?



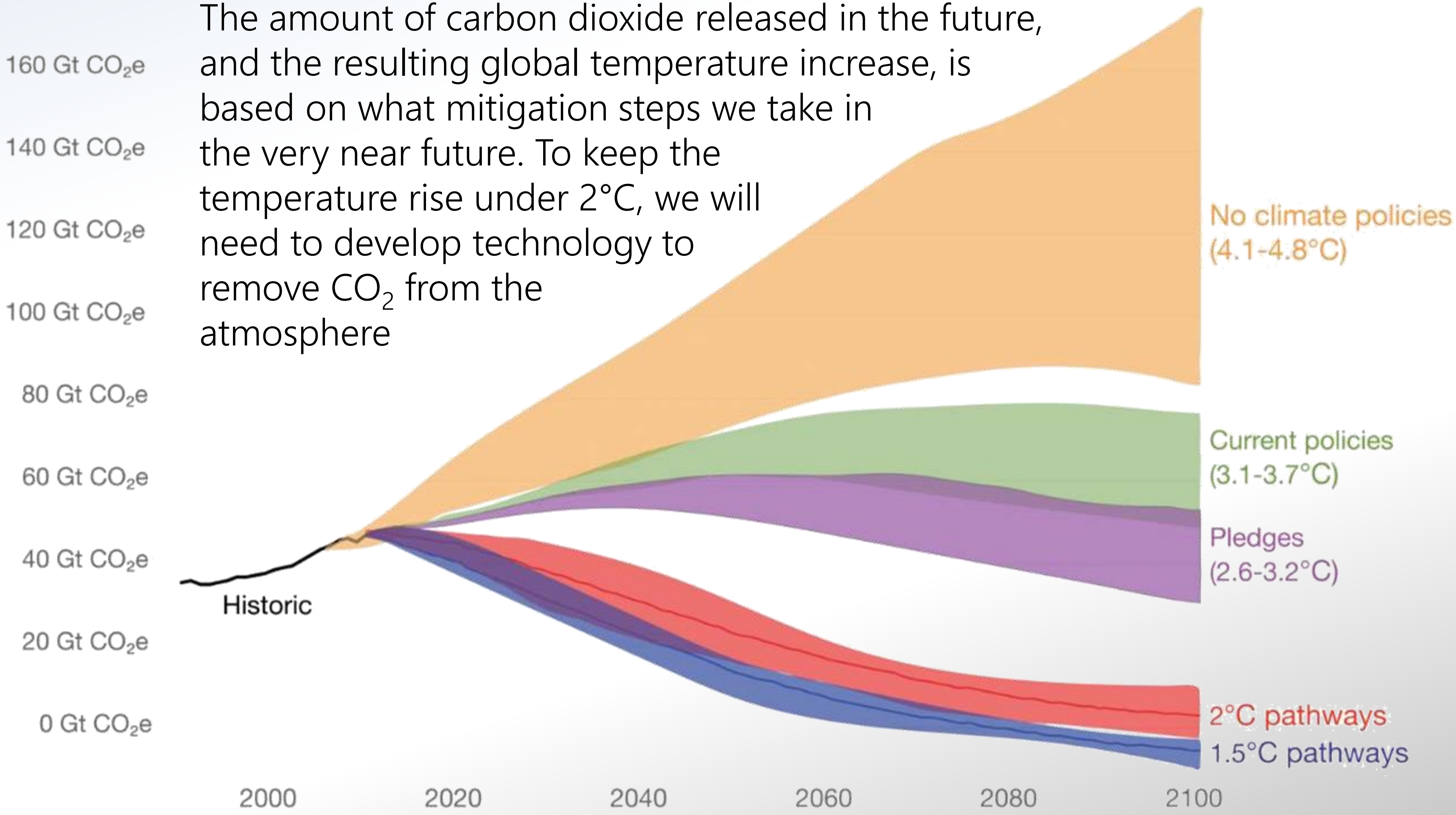
http://www.climatecentral.org/wmo-greenhouse-gas-bulletin-2015

www.freepik.com

https://ourplnt.com/global-warming-future-greenhouse-gas-emission-scenarios/global-future-greenhouse-gas-emission-scenarios/

Possible Emissions in the future

The amount of carbon dioxide released in the future, and the resulting global temperature increase, is based on what mitigation steps we take in the very near future. To keep the temperature rise under 2°C, we will need to develop technology to remove CO_2 from the atmosphere



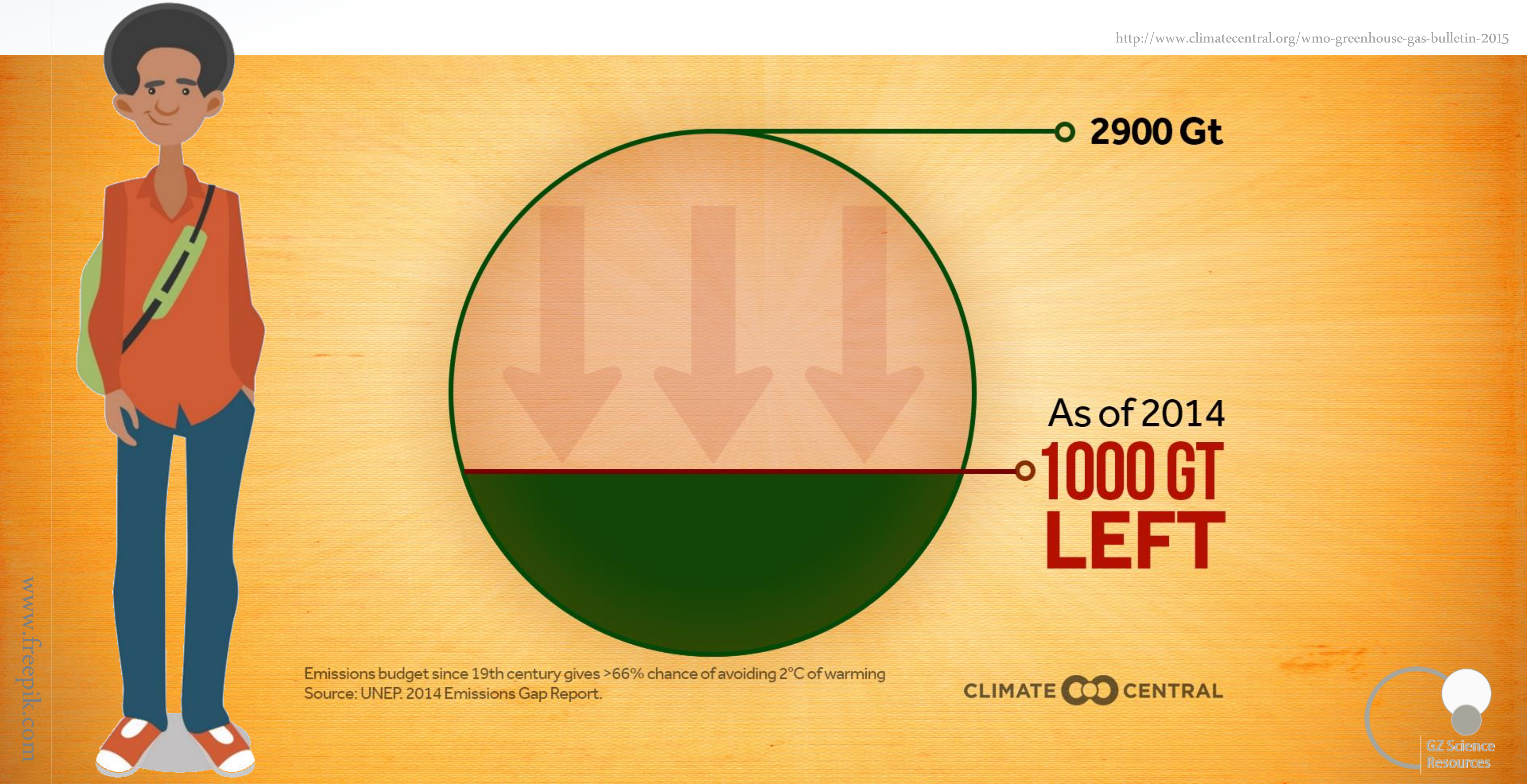
Based on data from the Climate Action Tracker (CAT).
The data visualization is available at OurWorldinData.org. There you find research and more visualizations on this topic.

What is the World doing about Climate change?

In 1997, most of the World's governments met together to agree on *the Kyoto Protocol* in 1997, and to reduce the amount of greenhouse gases they released by at least 5% by 2012.

In 2015 most governments (194 countries, including new Zealand) signed the *Paris Climate Agreement*, to reduce their greenhouse gases released so that the global temperature would remain below 2°c rise (above pre-industrial levels)

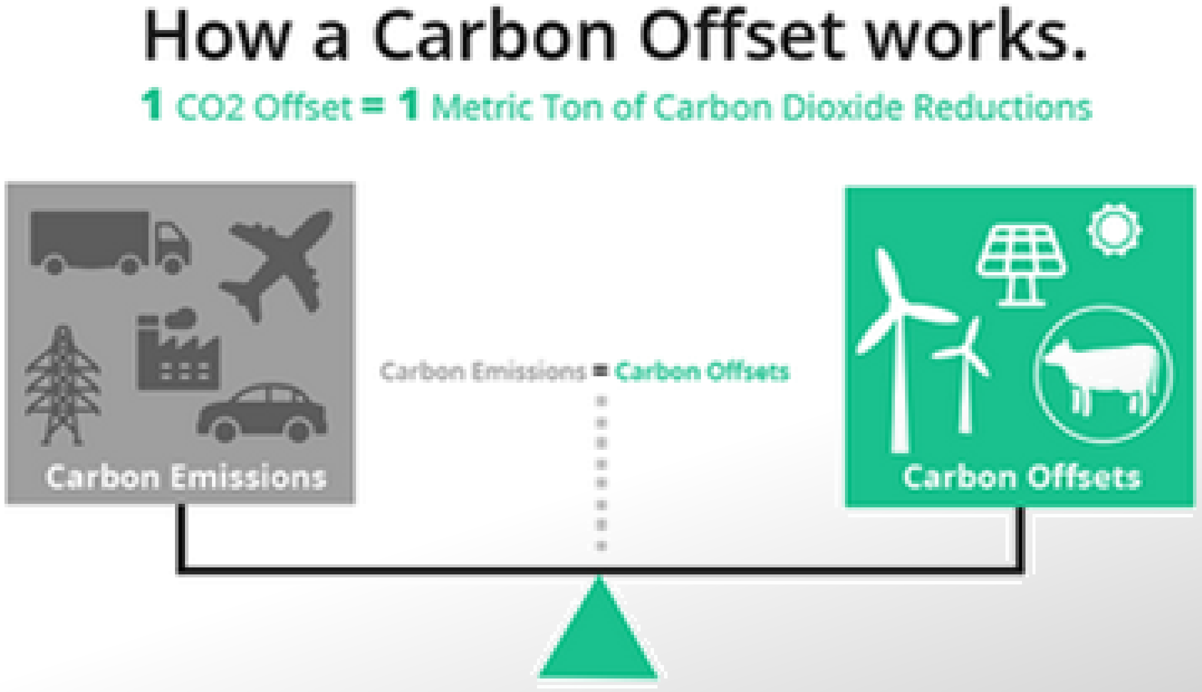
http://www.climatecentral.org/wmo-greenhouse-gas-bulletin-2015



Emissions budget since 19th century gives >66% chance of avoiding 2°C of warming
Source: UNEP. 2014 Emissions Gap Report.

What are carbon credits?

Carbon credits are given to 'developed' countries when they reduce their greenhouse gases (GHG). They are 'traded' away if they produce more GHG than agreed. They can be earned if they reduce GHG, or pay for a project in a 'developing' country to reduce their GHG, called 'carbon-offset programmes'



https://www.indiamart.com/proddetail/carbon-offsetting-19990545130.html

Mitigation to reduce greenhouse gases

Creating more of natural carbon sinks such as forestation, where the planting of trees utilises photosynthesis to draw CO_2 out of the atmosphere and store the carbon for longer periods as organic material

Using the oceans as a carbon sink, pumping in CO_2 gas.

Making and using alternative fuels and renewable energy that produce less CO_2 gas.

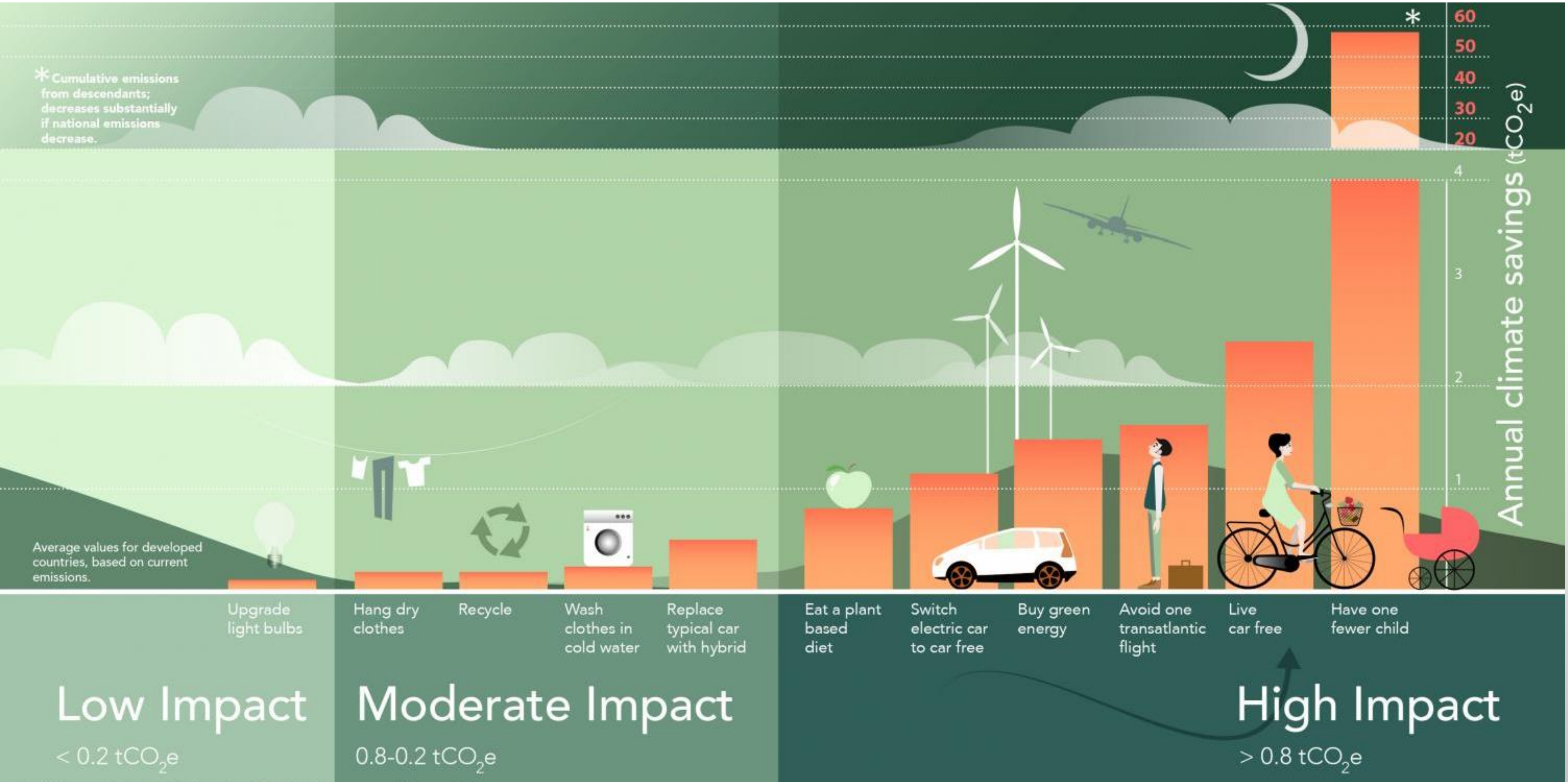
Creating geological storage, where CO_2 is pumped, then sequestered into 'porous' rocks, that can soak up the gas and store it for a long time

Capturing CO_2 gas from landfill (rubbish dumps) and fuel production, then storing it

Making alternatives to plastic, that use fossil fuels to make

What is a carbon footprint?

Industry and individuals have a role to play in mitigation by reducing their *carbon footprint*, the amount of CO_2 emitted each year in the course of production or daily life. Individuals can contribute by reducing their own carbon footprint, in small ways such as tree planting, reducing the energy used in their homes, switching to alternative fuels in their vehicles, or becoming involved in community projects. All of these small ways add up to a big help!

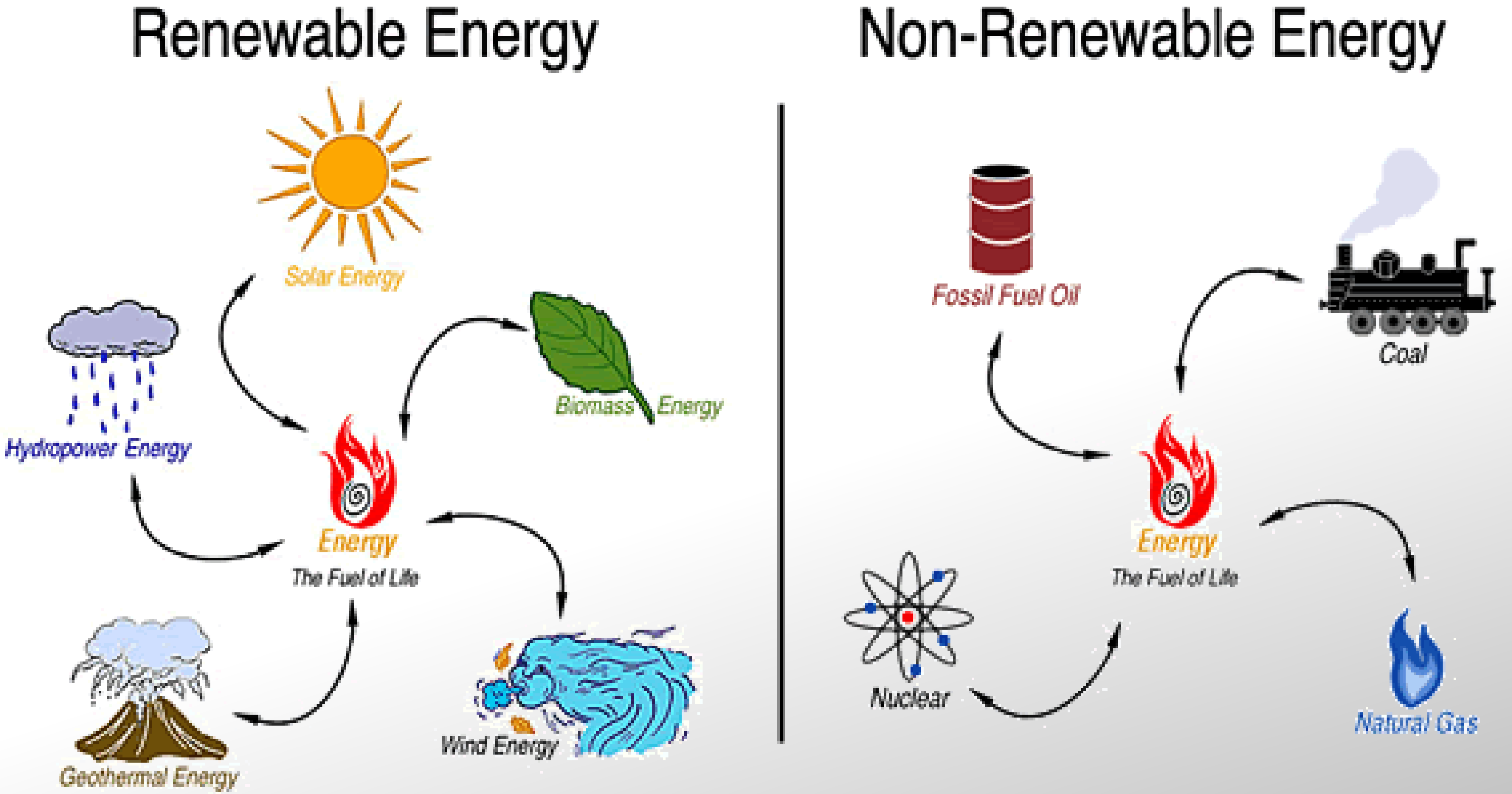


Seth Wynes & Kimberly Nicholas, 2017, Environmental Research Letters

https://phys.org/news/2017-07-effective-individual-tackle-climate-discussed.html

Renewable and non-renewable energy

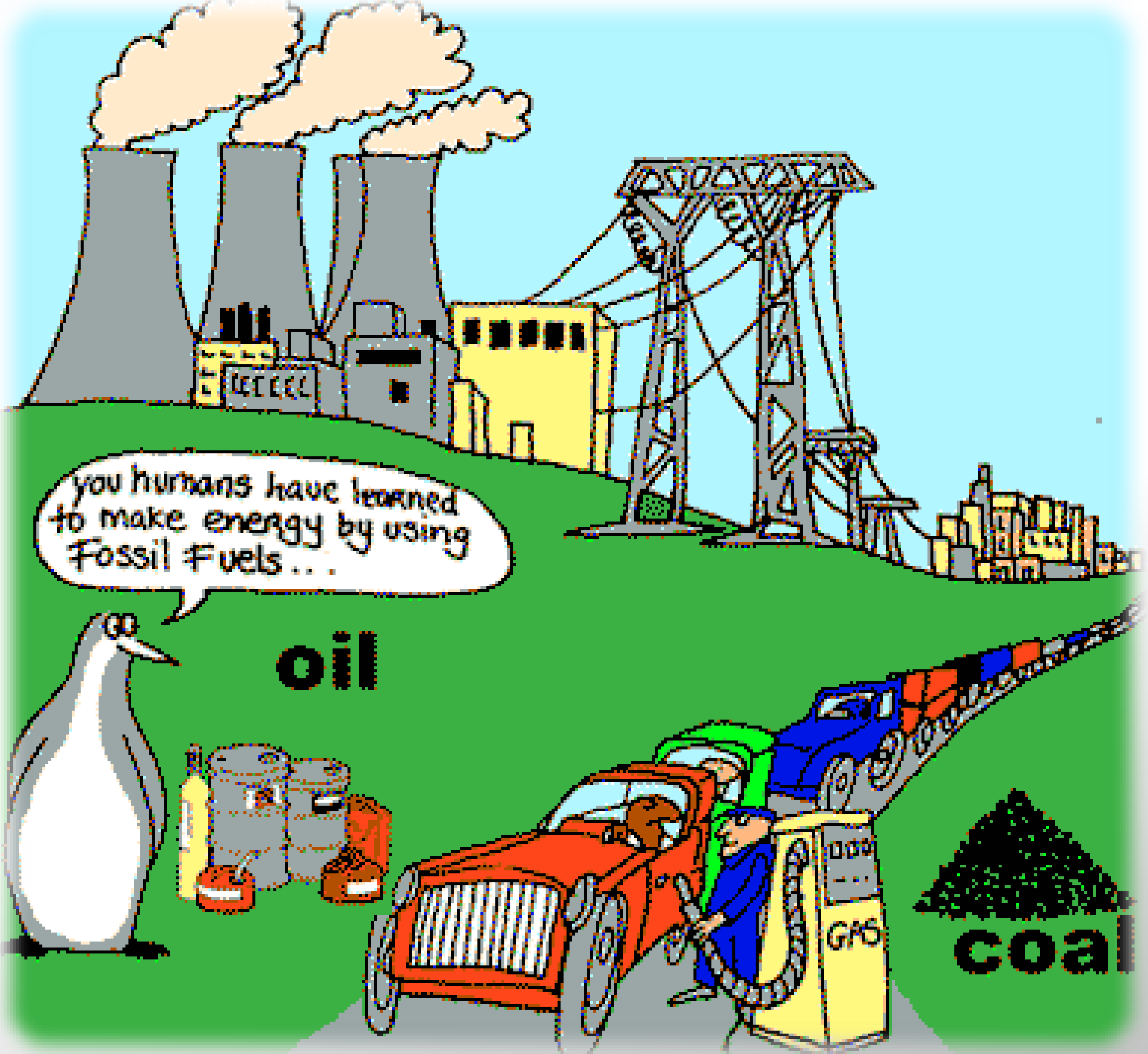
Energy sources can be divided into renewable and non renewable energy.
Renewable energy sources can be used continuously without running out. Renewable energy is available in unlimited amounts and technology has developed so we can convert it into electricity, heat and fuel for human use.
Non-renewable energy resources have often taken many millions of years to form and they are in limited supplies. Once they have been used up they can not be replaced.



Non-renewable energy

Non renewable energy is energy that comes from the ground and is not able to be replaced within a useful period of time. **Fossil fuels** are the main category of non renewable energy. Fossil fuels include; coal, oil and natural gas. These resources come from animals and plants that have died millions of years ago and then decomposed to create a useable source of energy for humans.

Mined minerals such as uranium used for nuclear power are also non renewable sources of energy.

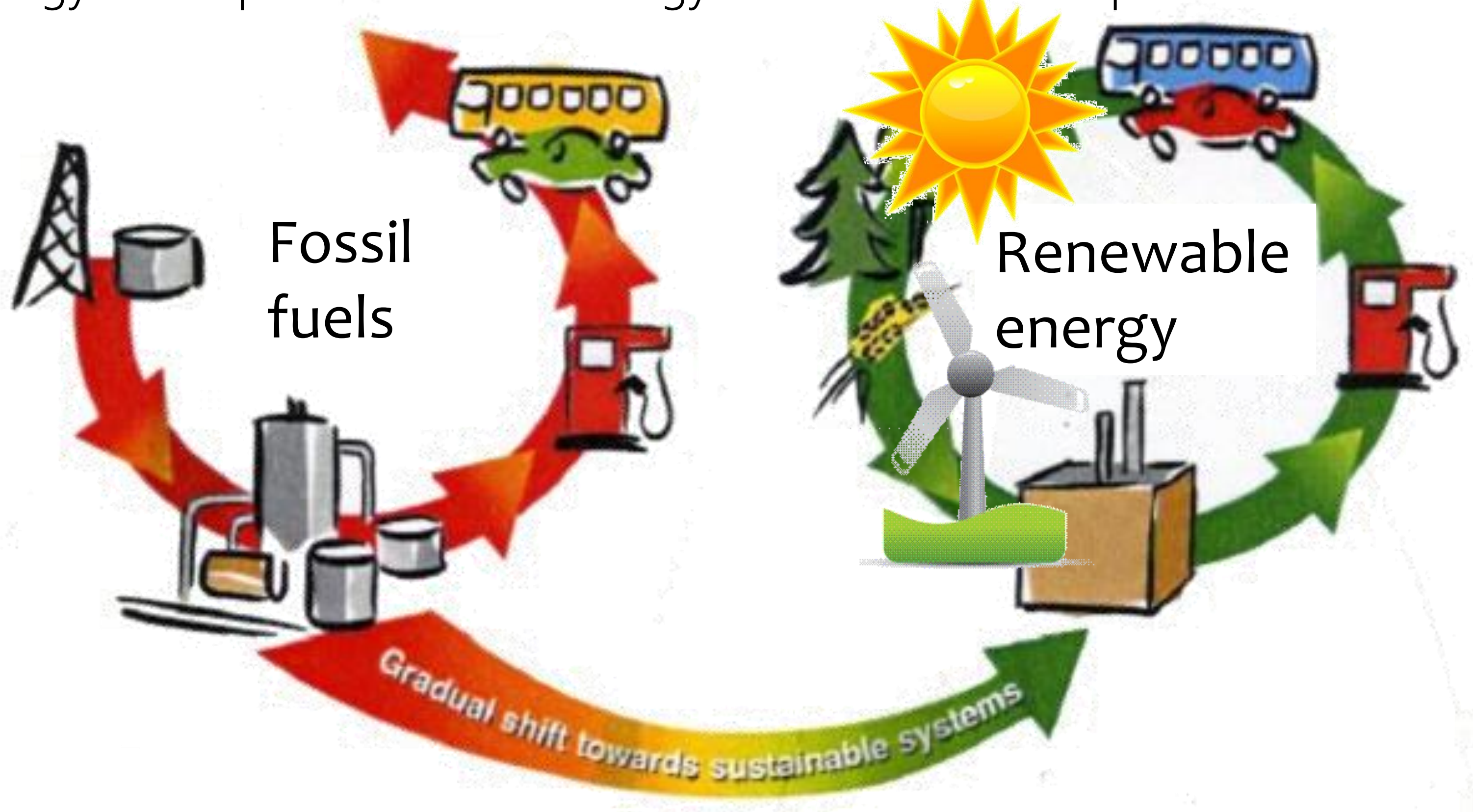


Renewable Energy

Energy is generated by the sun, and is stored in a variety of forms. It is locked into **biomass** through the process of photosynthesis. Burning biomass releases energy, as does decomposing biomass. Energy is stored in the oceans and fresh water where the movement of the earth and gravity release it through **tides** and **flowing rivers.** The earth's spin generate **waves** and **wind**. Heat, created from the center of the Earth, is released through **geothermal** activity. All of these energy sources can be used by humans.

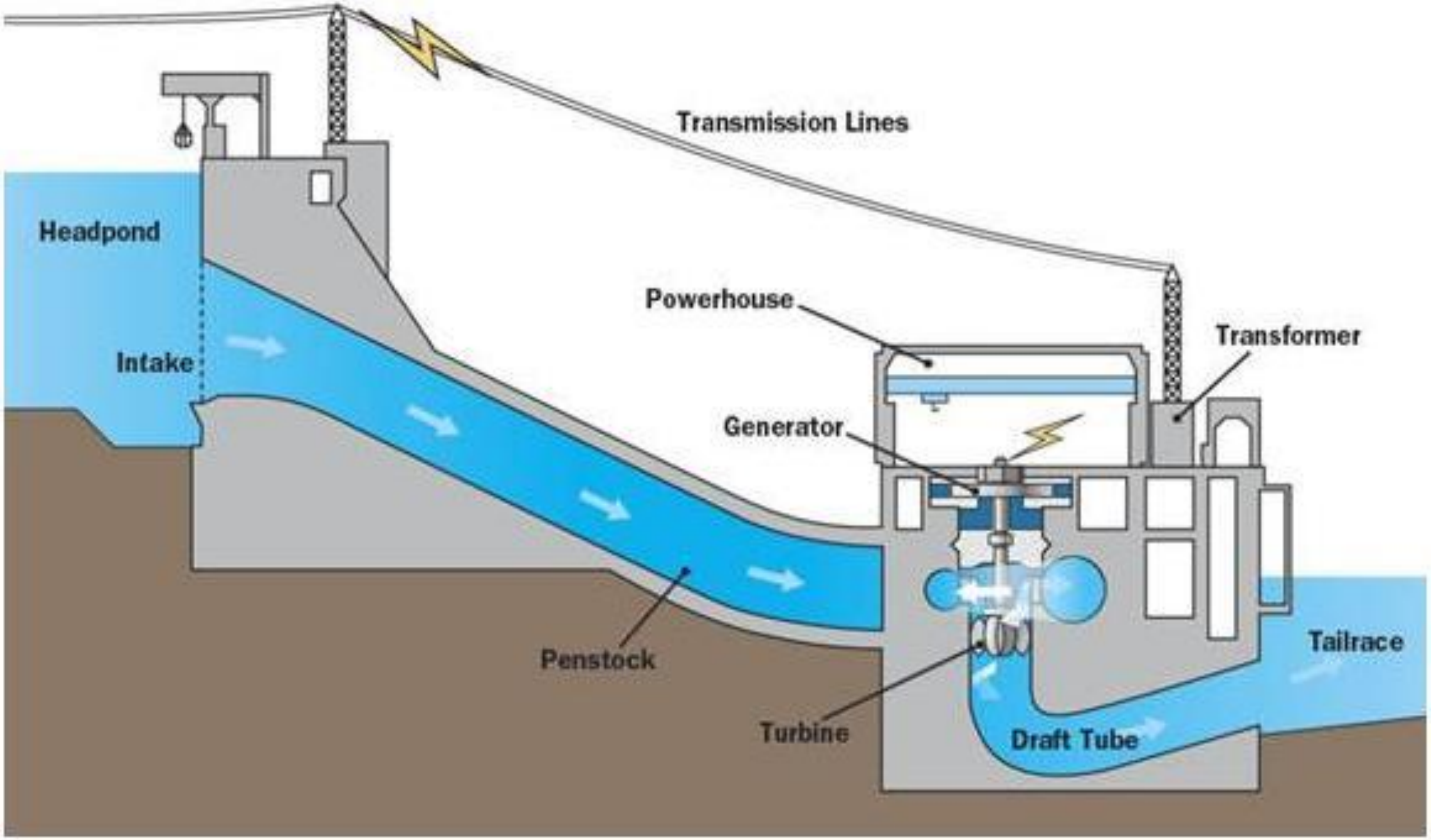
The limits of fossil fuels and the unlimited energy of the sun

Fossil fuels are a limited resource. Extraction and mining can be expensive and can damage the surrounding area. Carbon dioxide gas, that is released upon burning the fuels, are contributing to the warming of the climate. Human society has a dependence on fossil fuels for energy but needs to consider alternative renewable energy sources to replace decreasing coal, gas and oil supply. Renewable energy is sustainable and in many cases produces little or no harm to the environment. As new technology develops to collect the energy it will become cheaper.



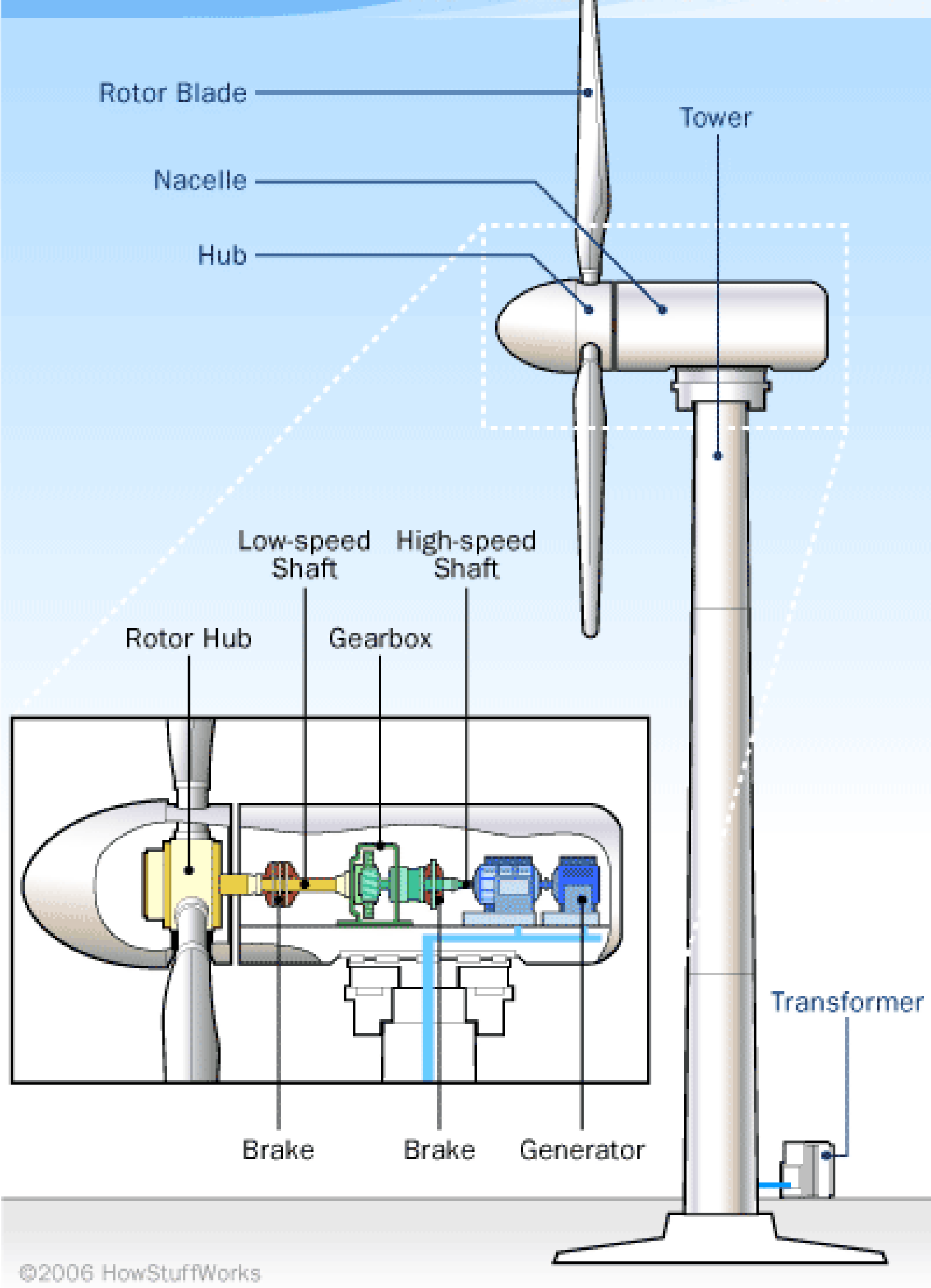
Hydroelectric Energy

Hydroelectric power makes electricity by using the energy from falling water. The water comes from big dams across rivers, and flows down great tubes to drive electricity generators. New Zealand is fortunate to have many rivers, such as the Waikato river, which are suitable to make use of this type of energy source.



Wind Energy

Wind power can drive a turbine with a propeller and generate electricity. Wind power is becoming more popular in New Zealand and a number of "farms" have been created such as along the hills in Manawatu and the new site between Hamilton and Raglan.



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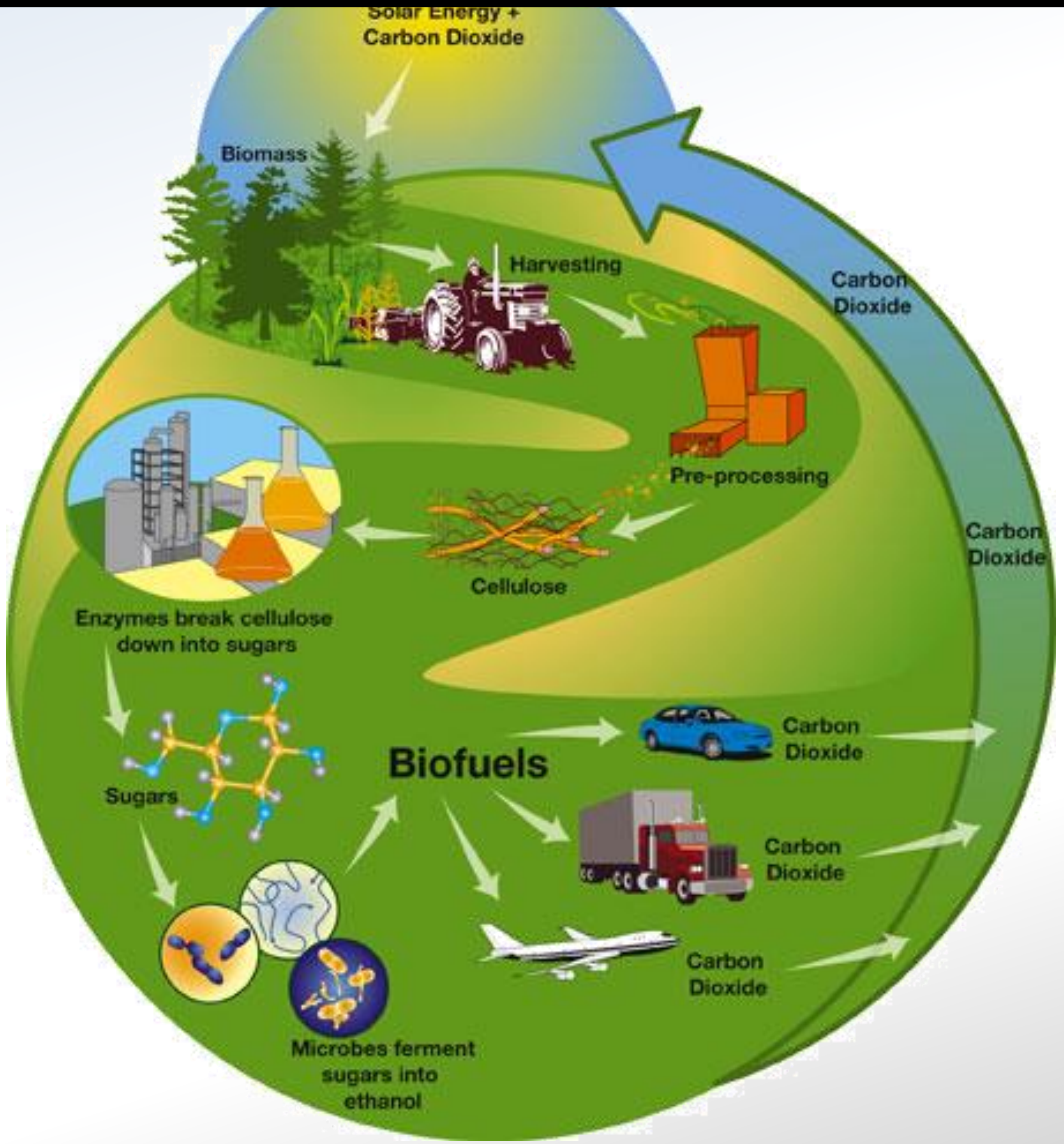
Solar Energy

Solar power can make electricity by using panels called **photovoltaic cells** which converts sunlight into direct current electricity. An inverter changes the direct current into alternating current which can then be used by households and industry to power machines and appliances.

Biomass Energy

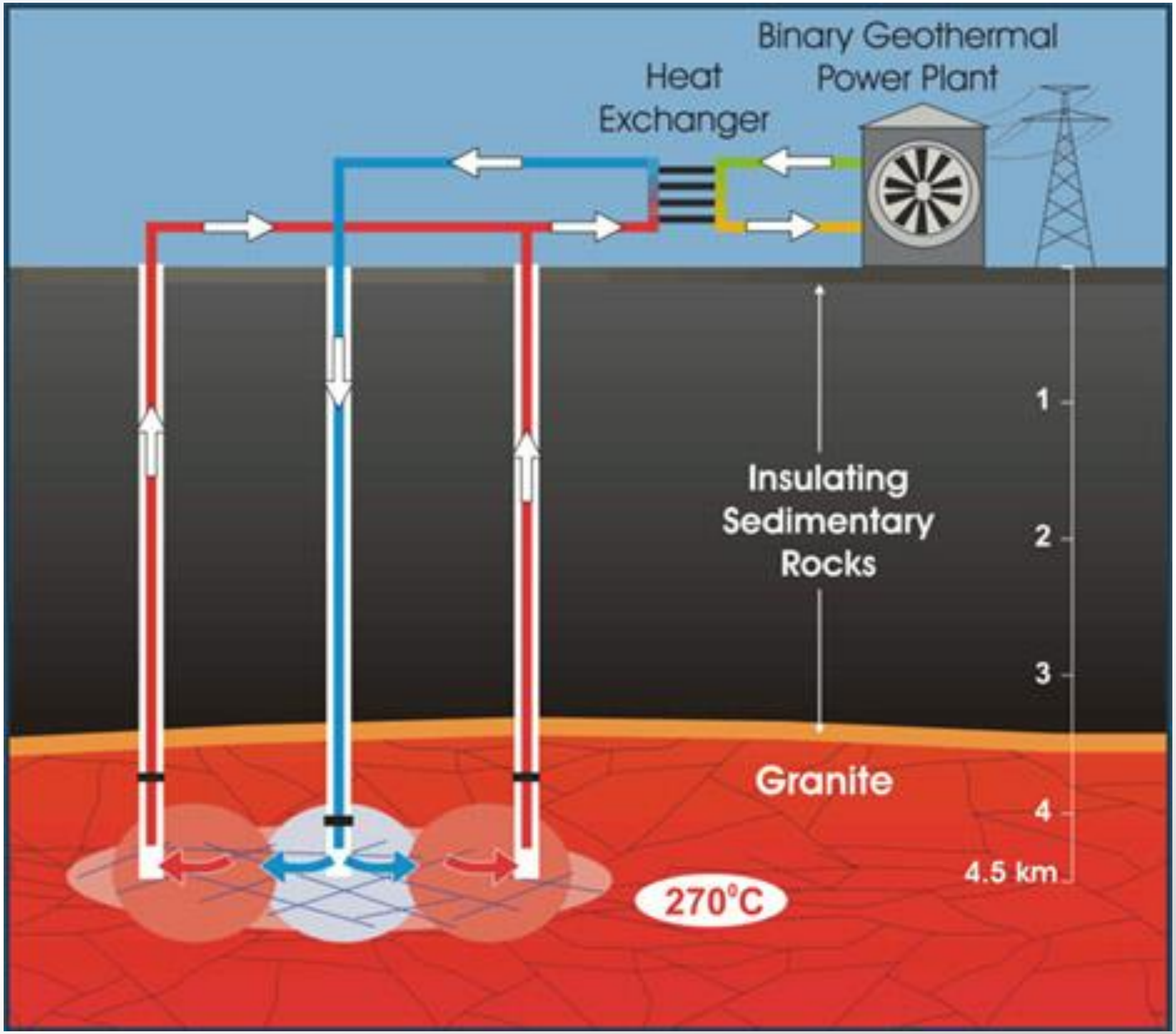


Biomass relies on the photosynthetic ability of plants to convert solar energy into chemical energy. The chemical energy stored in plants is then broken down by **enzymes** and useful **bacteria** into **biofuels** to be used in machinery.

This type of fuel is renewable as long as the same amount of trees are planted to replace those cut down. The carbon dioxide released when burning the fuels will also be reabsorbed by the plants as they grow.

Geothermal Energy

Geothermal energy can be used to heat water pumped underground into hock rocks and the steam created then powers turbines to create electricity. Hot steam that comes from naturally occurring vents can also be used.

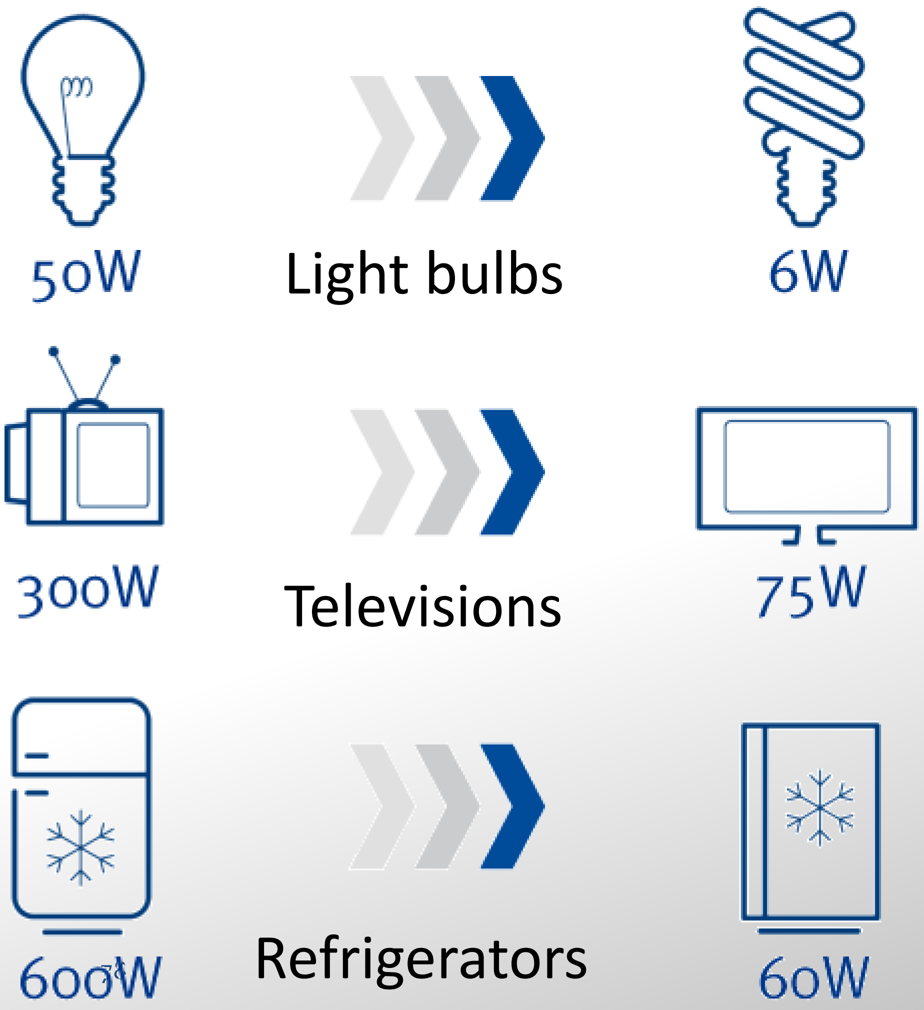


Summary of Renewable and Non-Renewable energy sources

Energy Source	Renewable/non-renewable	Advantage	Disadvantage
fossil fuels; oil, coal and gas	non-renewable will run out	*free if found *a small amount creates a lot of energy	*damaging to environment *adding to climate change *starting to run out
hydro	renewable not going to run out	*clean and non-polluting *free and cheap to run	*can destroy and flood land when hydro lakes are made *reduces flow of the river
solar	renewable	*free once set up and non-polluting	*does not run at night *solar panels can be expensive
wind	renewable	*free once set up and non-polluting	*turbines expensive to set up *noisy and some people do not like the look of them
nuclear	non-renewable	*very small amounts of chemicals needed for a lot of energy	*creates nuclear waste *can cause dangerous accidents with radiation
geothermal	renewable	*free once set up and non-polluting	*can only be used in a few areas
biofuel	renewable	*can be used in machinery that uses petrol	*creates pollution *needs land to grow plants
tidal	renewable	*free once set up and non-polluting	*only works at certain times and places

Becoming more energy Efficient

Appliances for use around the house are being designed to be more energy efficient. This means that they require less input energy to produce the same amount of useful energy output. Less waste energy is produced in the form of heat and sound.

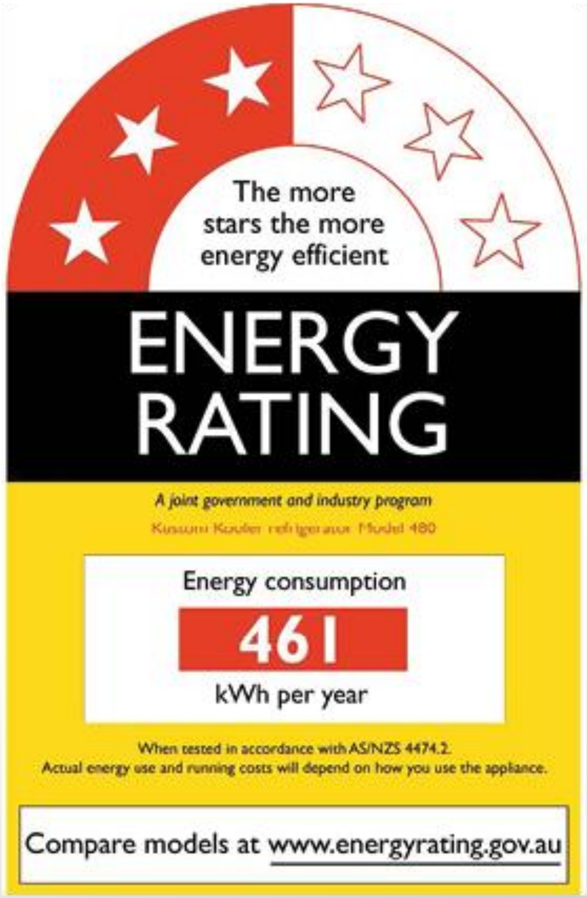


OLD		NEW
50W	Light bulbs	6W
300W	Televisions	75W
600W	Refrigerators	60W

Comparing household appliances for efficiency rating

Appliances are sold with an energy rating sticker. The more stars an appliance has the more energy efficient it is.
As similar appliances need to use approximately the same amount of useful energy, the more efficient appliances will save you money to run.

If less electricity is needed in many houses, then less electricity is required to be generated. This can have a positive impact on the environment if electricity generation uses fossil fuels.

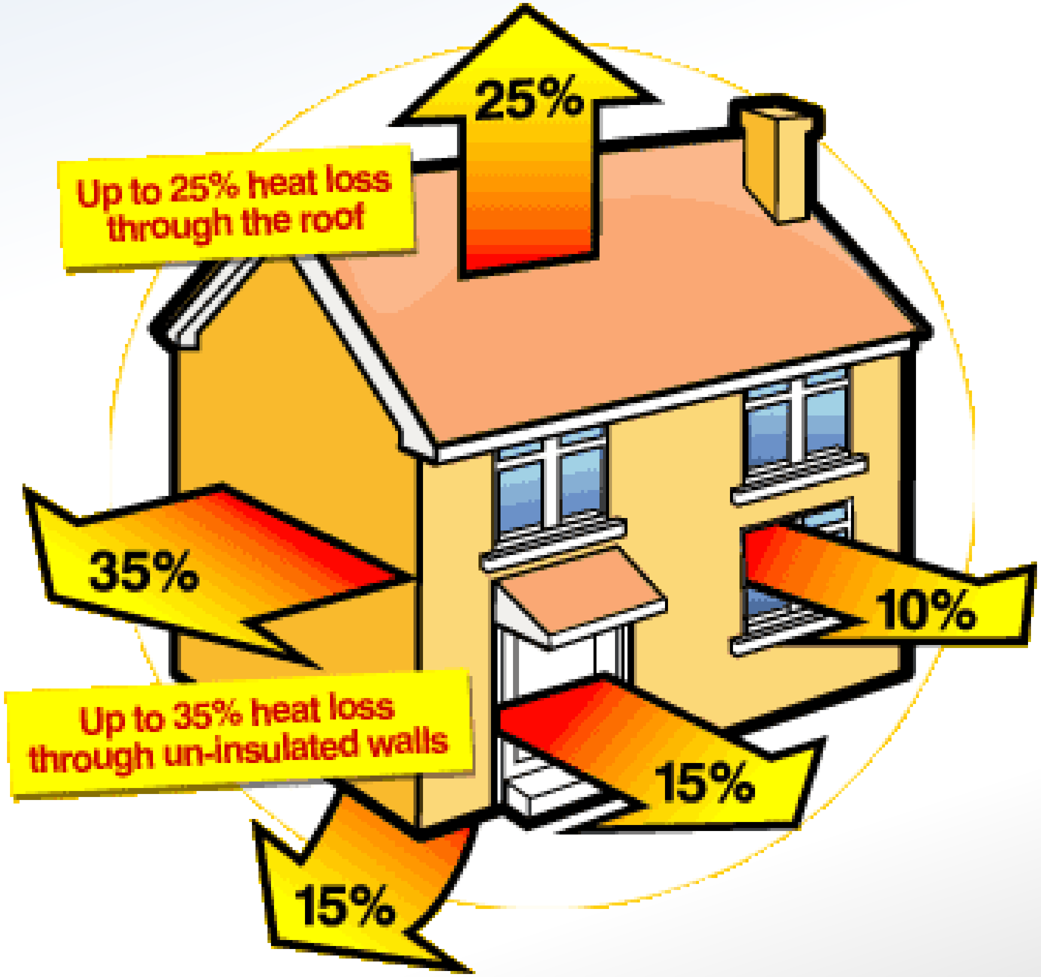


Energy Efficiency – comparing types of light Bulbs

	Incandescent	Compact Florescent	LED
Life Span (average)	1,200 hours	8,000 hours	50,000 hours
Watts of electricity used (equivalent to 60 watt bulb).	60 watts	13-15 watts	6 - 8 watts

Each of these types of bulbs produces the same amount of useful energy but require different amounts of input energy

Transformation losses, and inefficient use, increase the amont of energy required

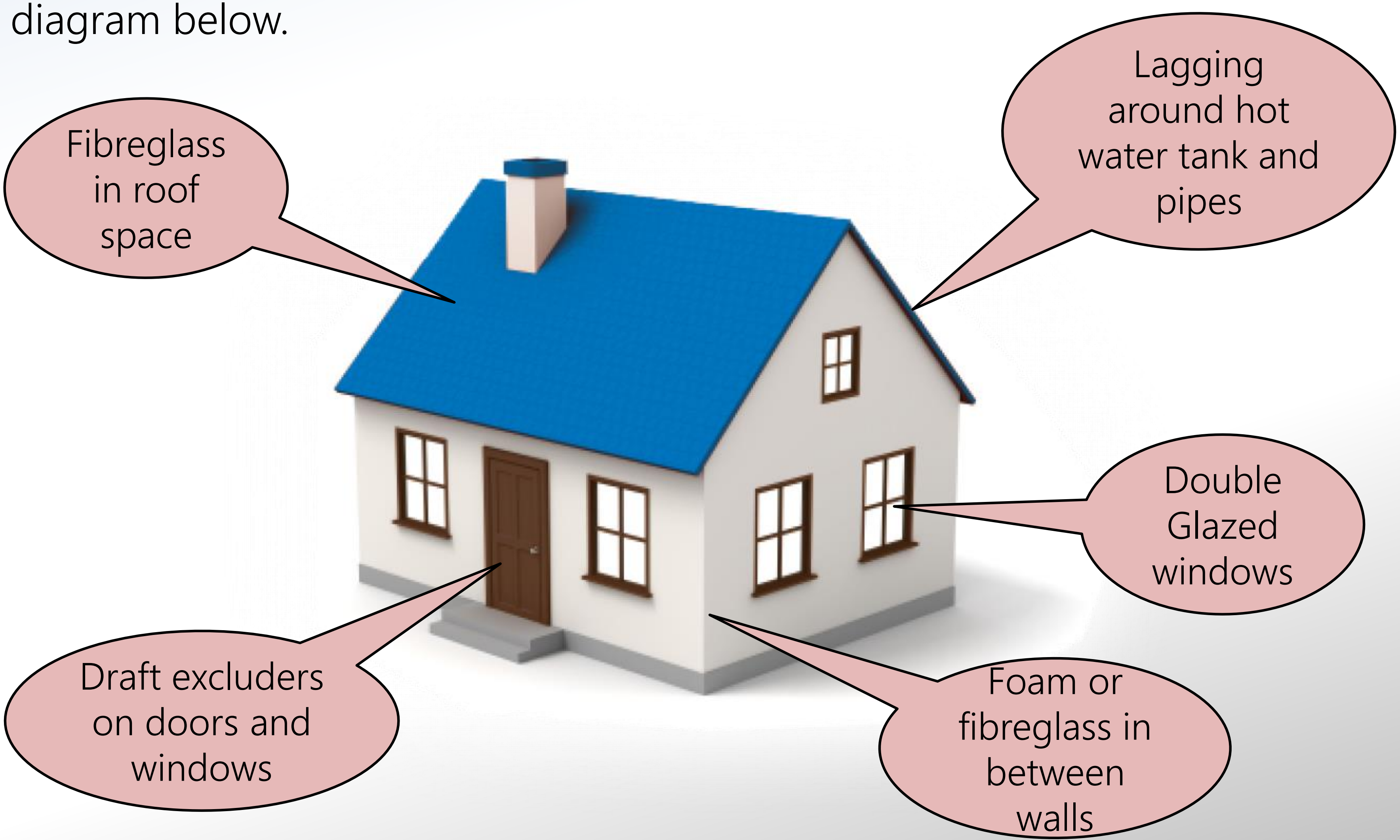


A large amount of energy use in a home is spent on heating. If a home is **poorly insulated** (with materials that do not conduct heat) then the heat will easily escape and more energy will be required to maintain the temperature to a suitable level.

Leaving lights on when not being used, using standard incandescent light bulbs instead of the CFL or LED bulbs and leaving appliances switched on at the wall when not in use are all inefficient uses of energy.

Reducing energy loss from our homes

It is important to reduce the loss of heat from our homes. This is done by increasing the insulation of our homes using the methods shown in the diagram below.



Fibreglass in roof space

Lagging around hot water tank and pipes

Double Glazed windows

Draft excluders on doors and windows

Foam or fibreglass in between walls

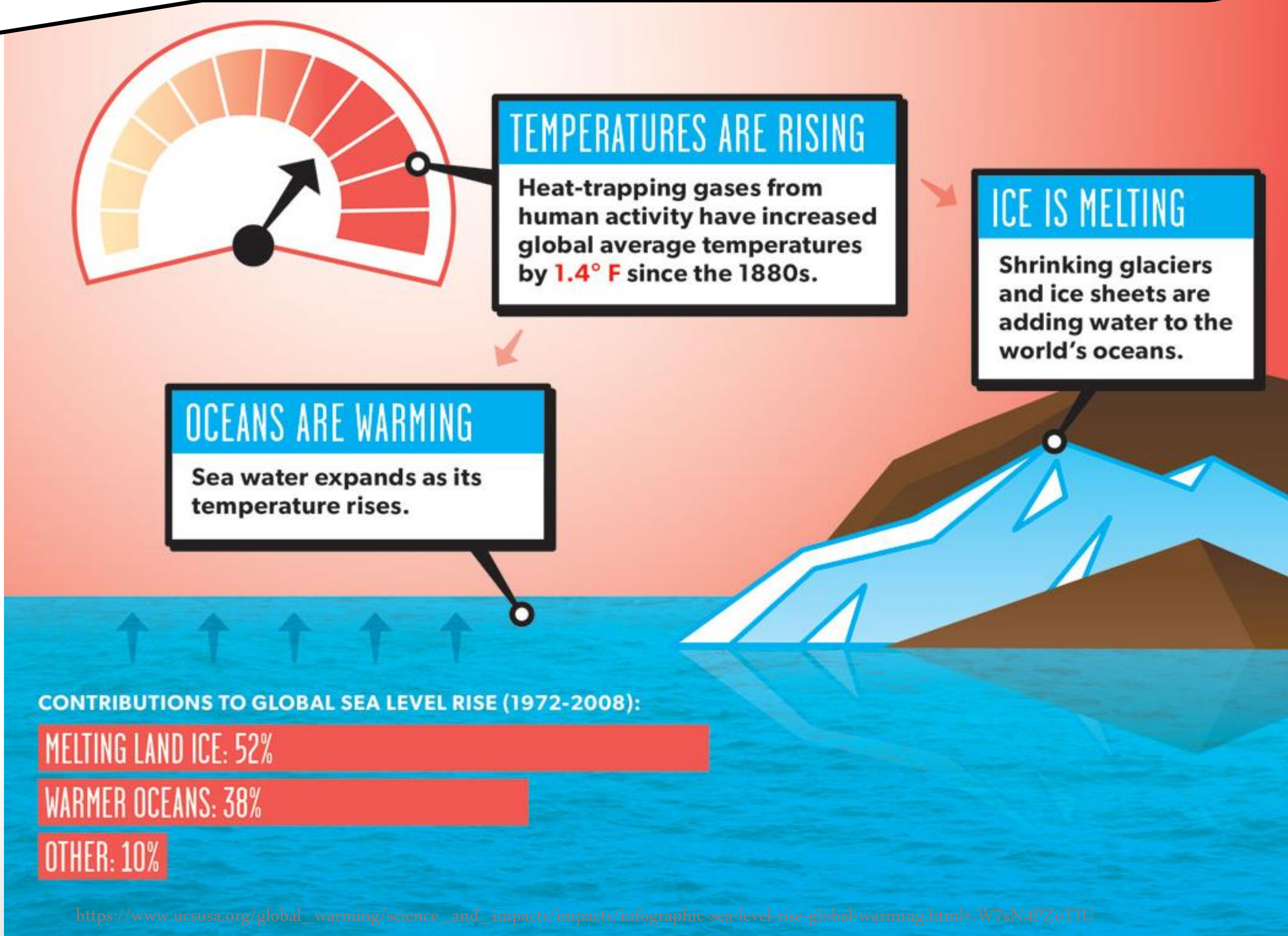
Summing up Climate Change

Almost all scientists now agree that human activity, producing CO_2 and other greenhouse gases, have changed the energy balance of the Earth, increasing the average temperature of the Earth, and this is permanently altering the climate around the globe. There is more carbon moving from other reservoirs of the carbon cycle into the atmosphere, than out of it, increasing the CO_2 concentration. Observations, data and computer now predict more accurately that temperature rise, sea level rise, and an increase of extreme weather events are due to climate change.

https://research.asu.edu/stories/read/series-carbon-and-climate-change

Summing up Climate Change

The main reason for increasing CO_2 in the atmosphere is the combustion (burning) of fossil fuels for industry, transportation, and energy (electricity mainly) generation. The greenhouse effect, due from CO_2 and other greenhouse gases, traps heat energy (originally light energy from the Sun), leading to a temperature increase on the Earth's surface. Increasing temperature is accelerating the melting of the cryosphere (frozen water on the Earth), causing the global sea level to rise.



TEMPERATURES ARE RISING

Heat-trapping gases from human activity have increased global average temperatures by 1.4° F since the 1880s.

ICE IS MELTING

Shrinking glaciers and ice sheets are adding water to the world's oceans.

OCEANS ARE WARMING

Sea water expands as its temperature rises.

CONTRIBUTIONS TO GLOBAL SEA LEVEL RISE (1972-2008):

https://www.ucsusa.org/global_warming/science_and_impacts/impacts/infographic-sea-level-rise-global-warming.html#.W7sN4PZoTIU

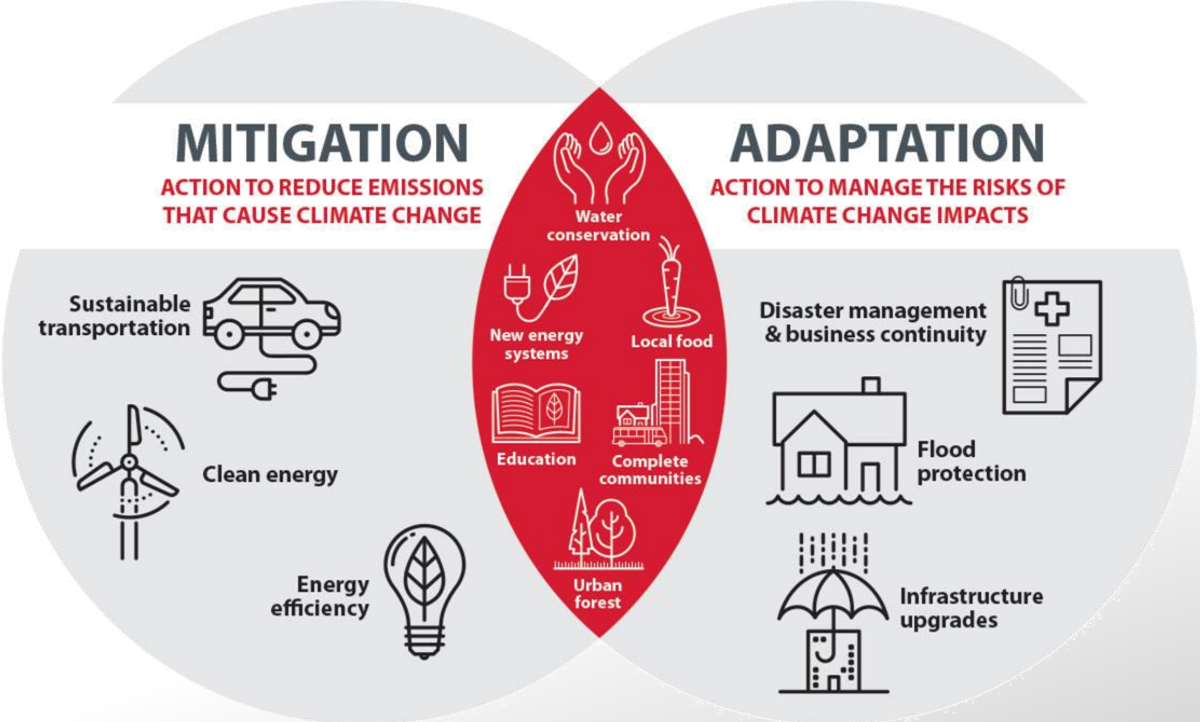
Summing up Climate Change

The average temperature in the polar regions is rising quicker than the rest of the planet, partly due to *albedo* reduction, as darker ground under the ice becomes exposed by the melting snow and ice.
In addition, oceans are acting as a major sink of anthropogenic (human-made) CO_2, and becoming acidified.

Governments, industry, and individuals are planning and initiating climate change *adaptation* projects to reduce projected harm to humans and ecosystems. Like many countries, New Zealand is also likely to experience a many consequences, and we must work with our communities to find the most appropriate solutions

Summing up Climate Change

Because current levels of human-made CO_2 will continue to cause a rise in global temperature, mitigation effects are required to reduce greenhouse gas emissions, Guidelines have been signed by many countries to help reduce greenhouse gas emissions, and therefore temperature increases.



http://www.calgary.ca/UEP/ESM/Pages/Energy-Savings/Climate-Change.aspx?master=old