ACT Climate Change Council

WHAT IS A CARBON BUDGET?

How is a 'carbon budget' relevant to the ACT?

Like a household budget, climate science sets a carbon budget for the amount of greenhouse gases that can be 'spent' (emitted) for a given level of global warming. If we exceed this budget, global temperatures will become higher.

This summary explains the concept of a carbon budget, and why it is useful in determining whether possible future actions on climate change will be sufficient to limit global warming below a certain temperature. The ACT Climate Change Council used a carbon budget to arrive at its recent recommendations for greenhouse gas (GHGs) emissions targets for the ACT.[1]

How Greenhouse gases cause Climate Change

GHGs trap heat in the lower atmosphere, warming the planet to a higher temperature that it would be without these gases.

In this way, GHGs help control the surface temperature of the Earth; when the amount of these gases increases for an extended period, the Earth warms. Natural processes can cause GHGs to fluctuate slowly, but the rapid global warming over the past 50–60 years is almost entirely due to GHGs released by human activity.[2]

The 3 main contributors to Climate Change are:

1. carbon dioxide
2. methane
3. nitrous oxide.

The main source of human carbon dioxide emissions is the burning of fossil fuels: coal, gas, petrol and oil. The manufacture of cement is also an important contributor to carbon dioxide in the atmosphere.

Methane is emitted in the production and delivery of fossil fuels, wet rice cultivation, and by livestock and the decay of waste in landfills.

Nitrous oxide is emitted during agricultural and industrial activities and in the combustion of fossil fuels and solid waste.

Carbon dioxide is the most important of the 3 main GHG contributions to global warming because of its higher concentration in the atmosphere.

This is why carbon dioxide (or 'carbon' for short) is the standard by which the warming effect of all GHGs is measured.

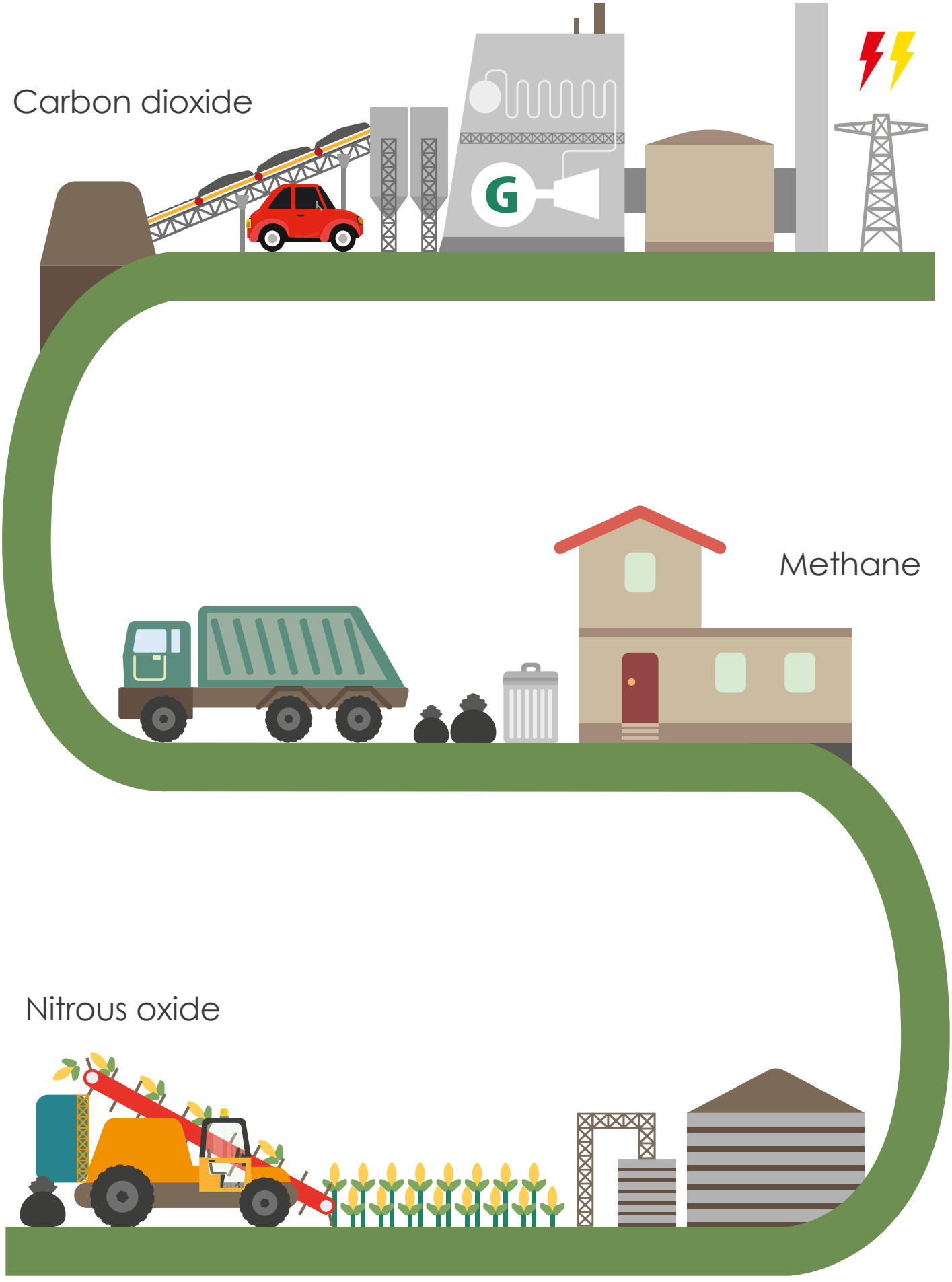
The importance of each GHG to global warming is due to three main characteristics:

- CONCENTRATION — the quantity of the gas in the atmosphere
- STRENGTH — the efficiency with which a molecule of the gas can trap heat
- LIFETIME — the typical time the gas remains in the atmosphere if not replenished.

Of these three characteristics, concentration is the only one that humans can directly influence. Strength and lifetime are determined by physics and chemistry.

The concentration of carbon dioxide in the atmosphere has risen sharply since the 1960s, almost entirely due to human activity. Furthermore, it is increasing at a faster and faster rate.

The 3 main contributors to Climate Change



Why are we on a budget?

Current global warming[3] of about 1°C is causing significant changes in the Earth's climate, most of which have negative outcomes for human and environmental health. Warming of more than 2°C would result in even more dangerous adverse impacts.

These impacts include[4] increased severity of storms and heat waves, species extinction, wildfires, coastal inundation from rising sea levels and increased storm surge, and the possibility of crossing so-called 'tipping points'[5] that would accelerate climate change and greatly intensify its impacts.

Limiting further warming requires decreasing the human 'spend' of GHG emissions and then reducing emissions to zero.

How increased carbon dioxide levels affect global temperature rise

The way in which the carbon dioxide moves through the land, ocean and atmosphere is complex, but the full effect yields a simple relationship between global warming and our actions.

The increase in global average surface temperature is related to the total amount of carbon dioxide produced by humans since the beginning of the industrial age, when human emissions began to become significant. So far, the relationship has been approximately 'linear,' meaning that if we double the amount of carbon dioxide produced, we essentially double global warming.

If we wish to hold warming to a desired temperature limit (for example, the Paris 1.5°C or 2°C targets) then the total amount of GHG emissions must be kept below the 'carbon budget' set by nature for that amount of warming.

The budget is not an annual one, but rather a cumulative one; for all time—past, present and future. Furthermore, the carbon budget cannot be modified to suit the desires of humans; it is a fundamental feature of the way the Earth works. Once the carbon budget has been 'spent', then net emissions must be held to zero from that point onward in order to avoid exceeding the temperature target.[6]

How are we faring against the 1.5°C and 2°C Paris targets?

As one might expect, the 'carbon budget' for holding warming to no more than 1.5°C is smaller and more inflexible than for 2°C. The budgets are usually measured in tonnes of carbon. Let's start with the carbon budget for keeping global temperature within 2°C, much of which has already been spent.

Estimating the carbon budget to meet the 2°C Paris target

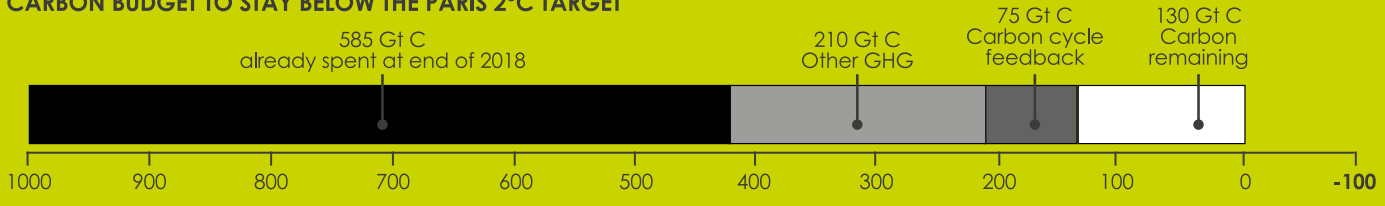
Let's assume that we want a good chance of meeting the 2°C Paris target. The UN International Panel on Climate Change (IPCC) estimates[7] that for at least a 66% chance of staying below 2°C, total GHG emissions must be less than 1000 billion tonnes of carbon.

We have already 'spent' about 585 billion tonnes (also referred to as gigatonnes)[8] of carbon (Gt C), which reduces the remaining carbon budget to about 415 Gt C. Then we need to account for the other GHGs, principally nitrous oxide and methane. If we don't reduce them at the same rate as we reduce carbon dioxide we'll have less of the budget—about 210 Gt C less—to still 'spend'. That leaves about 205 Gt C. The current rate of emissions of carbon dioxide is about 10 Gt C per year, so at present rates this remaining budget would be used by about 2040.

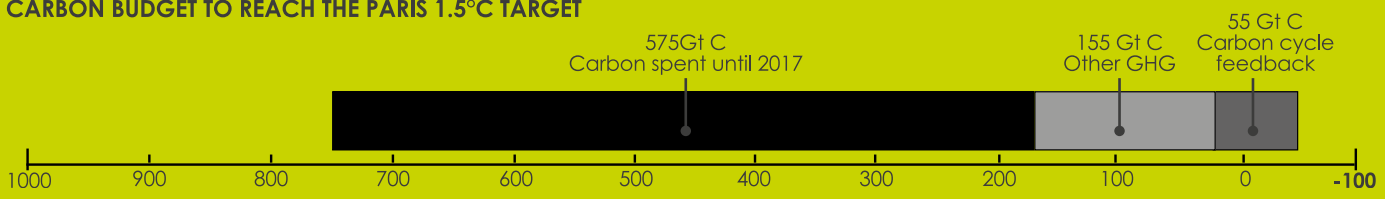
What are carbon cycle feedbacks?

There is one more remaining factor that reduces our budget and our time to reach net zero emissions. As the Earth warms, the oceans and land are no longer able to absorb the same fraction of our carbon emissions that they can at lower levels of warming, an effect due to 'carbon cycle feedbacks.' Combining scientific estimates of this effect by two independent groups[9],[10] indicates that the budget previously calculated must be revised downward by about 75 Gt C. This leaves a remaining carbon budget for keeping global temperature within 2°C at 130 Gt C. Once this is spent, net GHG emissions must stay at zero. Without a change in the current global spend rate of 10 Gt C per year, we have only 14 years (before 2035) to reach net zero emissions to stay below 2°C of warming.

CARBON BUDGET TO STAY BELOW THE PARIS 2°C TARGET



CARBON BUDGET TO REACH THE PARIS 1.5°C TARGET



Estimating the carbon budget to meet the 1.5°C Paris target

Using the same approach, and information in the most recent IPCC report, an estimate can be made of the remaining carbon budget to keep global warming at or below the 1.5°C Paris target.[11]

The baseline carbon budget for the 1.5°C target is 740 Gt C, assuming again that we want at least a 66% chance of meeting this target. Historical emissions of 585 Gt C already 'spent' again must be subtracted from the baseline budget.

The cost of not reducing the other GHGs and the cost of carbon cycle feedbacks need to be adjusted in order to be compatible with a 1.5°C target. Using a simple linear adjustment, these allowances are 155 Gt C and 55 Gt C, respectively.

This leaves a remaining global carbon budget of -55 Gt C.

What does it mean if the forward carbon budget for 1.5°C is negative?

It means that we have likely already exceeded nature's budget to hold warming below 1.5°C. We have 'overshot' that target or, as scientists say, we are 'in overshoot'.

Why have I heard that we have more time and that holding warming to 1.5°C is possible?

Some studies claim that meeting a 1.5°C target is still possible, and that emissions needn't drop to zero until 2050 or later to meet the 2°C target. These optimistic-sounding scenarios feature one or more of the following characteristics:

- Less than 66% odds are accepted for meeting the target
- Temperature overshoot is accepted before the planet later cools to finally reach the target
- Feedbacks that increase warming are ignored or underestimated
- Methane and nitrous oxide emissions are reduced at the same rate as carbon dioxide emissions
- An assumption is made that unproven or yet-to-be-discovered technology will pull carbon dioxide out of the atmosphere in quantities greater than humans add it to the atmosphere.

On the other hand, the analysis presented in this summary uses a strict definition of holding warming to a target temperature, makes use of the most recent science on carbon feedbacks, and relies on currently available technology or modest advances in the next 15 to 20 years.

How can the ACT contribute its fair share to a safer, more stable climate?

100% renewable ELECTRICITY BY 2020

The ACT Climate Change Council considered the following data and norms in arriving at its recommended GHG targets for the Territory:

- The latest science indicating more severe negative impacts at lower temperatures
- The ACT's 'share' of the world's remaining carbon budget for **keeping global temperature within 2°C**
- Independent feasibility analysis based on currently available technologies
- The ACT ambition to be a leader in reaching net zero emissions
- Ethical considerations for future generations and the less advantaged.

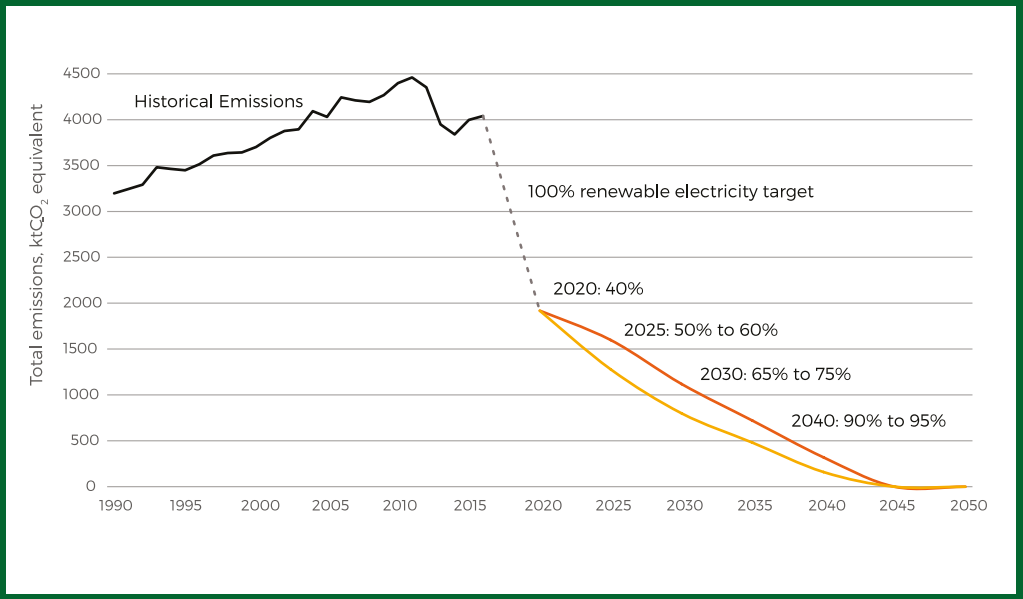
If we assume that the ACT population will reach 500,000, and the world's population 8.5 billion, between 2030 and 2040, we can calculate the ACT's share of the remaining carbon budget on an equal per capita basis.

Doing so yields 7.6 Mt C (7.6 million tonnes of carbon) as the remaining budget from now until the Territory reaches net zero emissions. This becomes 28 million tonnes[12] when converted into tonnes of CO_2-e (carbon dioxide equivalent).

This measure allows other GHGs to be included, which is a common approach. At the current rate of 'spend' by the ACT of 4 Mt CO_2-e per annum, this budget would be expended in about seven years.

But in the Territory, the past may not be a good predictor of the future. ACT emissions have been dropping rapidly since 2016 due to new renewable electricity supplies becoming available as a result of the Territory's 100% renewable electricity by 2020 policy. Using up-to-date information[13] for ACT emissions, the 'spend' of the Territory would be 28 Mt CO_2-e if the higher (red) emission trajectory is followed, and 23 Mt CO_2-e if the lower (orange) trajectory is achieved.

The graphic below shows the ACT's emissions 'spending" every year. This must decrease in order to meet our carbon budget.



The dashed line shows the effect of the 100% renewable electricity by 2020 policy. Orange and red lines are the lower and upper emission paths proposed by the ACT Climate Change Council for the Territory.

Staying within these lines ensures the ACT is within its share of the global 2°C carbon

Which path would you choose for the ACT?

Do you agree that the ACT should stay within its 'share' of the global 2°C carbon budget?

What emissions path would you recommend for the Territory from 2020 into the future?

Let us know, or send us any other feedback and questions to the ACT Climate Change Council at ClimateChangeCouncilSecretariat@act.gov.au.

Footnotes

1 ACT Climate Change Council letter to Minister Rattenbury, 19 October 2017. Accessed at: https://www.environment.act.gov.au/__data/assets/pdf_file/0004/1135876/20171019-Letter-from-ACT-Climate-Change-Council-to-Minister-Rattenbury-interim-targets.pdf.

2 IPCC (2013) Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker TF, et al. Cambridge and New York, Cambridge University Press, pp 3-29.

3 NASA (2018) (National Aeronautics and Space Administration) Global Land-Ocean Temperature Index. Accessed at https://data.giss.nasa.gov/gistemp/graphs_v3/Fig.A2.gif.

4 IPCC (2014): Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field CB, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, TE Bilir, M Chatterjee, KL Ebi, YO Estrada, RC Genova, B Girma, ES Kissel, AN Levy, S MacCracken, PR Mastrandrea, and LL White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

5 Schellnhuber HJ, Rahmstorf S, Winkelmann R (2016) Why the right climate target was agreed in Paris. *Nature Climate Change*, 6:649-653.

6 Even then, the temperature will keep rising for a while due to the lag between the time of the emissions and the time until the ocean and land have fully exchanged heat so that the surface warming stops.

7 IPCC (2013) Summary for Policymakers. In: Climate Change 2013: *The Physical Science Basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker TF, et al. Cambridge and New York, Cambridge University Press, pp 27-28 and Figure SPM-10.

8 This amount of carbon corresponds to about 2100 Gt of CO_2.

9 Steffen W, Rockström J, Richardson K, Lenton TM, Folke C, Liverman D, Summerhayes CP, Barnosky AD, Cornell SE, Crucifix M, Donges JF, Fetzer I, Lade SJ, Scheffer M, Winkelmann R and Schellnhuber HJ (2018) Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences (USA)*, doi:10.1073/pnas.1810141115.

10 Lowe JA, Bernie D. 2018 The impact of Earth system feedbacks on carbon budgets and climate response. Phil. Trans. R. Soc. A 376 : 20170263. http://dx.doi.org/10.1098/rsta.2017.0263.

11 IPCC (2013) Summary for Policymakers. In: *Climate Change 2013: The Physical Science Basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, edited by Stocker TF, et al. Cambridge and New York, Cambridge University Press, pp 27-28 and Figure SPM-10.

12 In advice given last year, the ACT Climate Change Council estimated the remaining GHG budget for the ACT to be 48 Mt CO2-e. Consideration of the new carbon feedback results has reduced budgets by about one-third.

13 Saddler, Hugh (2017) ACT Greenhouse Gas Inventory for 2016-17.

What is a Carbon Budget, published by the ACT Climate Change Council in 2018. Authors: Penny Sackett, Will Steffen and Karen Jesson.