"There weekly arrive in this town scores of green Vermonters and New Hampshire men, all athirst for gain and glory in the fishery. They are mostly young, of stalwart frames; fellows who have felled forests, and now seek to drop the axe and snatch the whale-lance."

Herman Melville — *Moby Dick*, 1850

4 Global warming science

The first strand of this book concerns the effect on people's health of following *Total Wellbeing Diet* (TWD) and its recommended manner of eating. The second strand concerns the impact of producing the foods favoured by TWD on Australia's land and water systems. We are now introducing the third strand. This is the impact on the planet's climate of large scale global meat production. This chapter will be a little tougher to read than previous chapters. One major problem with the public's understanding of global warming is that the science has been oversimplified to the point of being false. So this chapter needs to unsimplify things — just a little.

When Herman Melville wrote the lines in *Moby Dick* that form this Chapter's opening quotation, he was talking about men anxious for the adventure of whaling. These were *real men* and Melville realises that felling a forest and killing a whale are similar activities. Both involve overpowering nature with sheer physical brute strength.

Melville's stalwart forest fellers turned whale slaughterers released vast amounts of carbon dioxide (CO_2) into the air as they knocked down about a million square kilometers of the forests of North America. While about 70% of that CO_2 has been absorbed, some 30% of it is still up there. It's like a visitor who refuses to leave when you really want to go to bed. Methane has the chemical formula CH_4 and contains a carbon atom, just like carbon dioxide with the formula CO_2. Both are greenhouse gases, meaning they trap heat, but methane has a very short atmospheric lifetime. Methane is transformed into CO_2 fairly quickly, and this is absorbed like any other CO_2. About 70% of every tonne of methane emitted is no longer methane after 10 years, and almost nothing is left after 20 years[46] — it will all have been converted to CO_2.

This means that almost all the methane up in the atmosphere today is less than 20 years old. Our generation put it up there — not Melville's. Methane emissions come from both natural and human sources — we call the latter anthropogenic emissions. Anthropogenic methane emissions are about 60% of all emissions.

We are now making methane so quickly that the ratio of methane to CO_2 has doubled in the past 200 years. The microbes in the guts of animals, particularly ruminants like sheep and cattle, take the carbon atoms (C) from the plant matter they break down and hook these carbons up with four hydrogen atoms (H) to make methane (CH_4). The plants got their carbon from the air. This little microbe trick effectively takes CO_2 from the air and puts it on steroids for about a decade as far as its warming impact is concerned. For the decade or so that a tonne of methane is in the atmosphere, it has 72 times the warming impact of a tonne of CO_2[47].

So when you look at the sky and consider the increase in CO_2 we have to deal with, you may perhaps take comfort in the fact that it isn't all our fault. We, like our children, and their children, are paying for the accumulated sins of a line starting from even before Melville's stalwart fellows. A line running through to our fathers and their fathers as well as ourselves. Clearly, human-made global warming started a long time ago. Exactly *when* is a matter of great interest but little importance. At least one sensible estimate places the start of anthropogenic global warming at about 8,000 years ago.[48]

But, we will begin with a summary of the basic science. Interestingly, the type of balance experiments that are crucial in so much nutritional research are also important in climate change research. In nutrition research it is common for people and other animals to be placed in sealed containers — rather like big tin cans with various tubes sticking out — called *respiration chambers*. Here the heat generated by their bodies can be accurately measured. When people eat and move, they generate heat, and this can be measured very precisely with these chambers.[49] Have you ever wondered how nutritional calorie counters are built? The principle is simple, but the details are complex — isn't that always the way? The basic principle is that you put the food in a container floating in some water and you burn the food and measure the change in the temperature of the water. The device is a bit like a thermos with an insulated water layer. Burn some lettuce and the change is tiny. Burn a fatty rasher of bacon and the change is substantial. In your body, food isn't 100% digested. If it was, you would have no faeces. But that's one of those complex technical details that the people who do things like this for a living have to worry about.

The planet is just like one big respiration chamber and scientists can measure the difference between the energy arriving from the sun and the energy leaving as the earth gets hot and radiates heat out through the atmosphere.

4.1 Energy budget

The difference between the energy arriving at the planet and the energy leaving, is called the planet's *radiative budget*.

You body's calorie budget would carefully measure calories in and calories out — the energy you expended either running, walking or just plain sleeping and breathing. Energy enters your body in the form of food and the amount of energy is measured as calories. As far as the planet is concerned, all primary energy arrives at the earth's surface as sunlight and is measured in watts — just like the electricity in your house. If you eat more energy than you expend, you will put on weight and get bigger. Your bigger body will require more energy to do the same work and eventually you will reach a size where your energy expenditure equals your energy intake. For example, if you have a stable weight of 72 kg and a stable calorie intake of 2800 calories per day and you increase your intake by 200 calories per day, then your weight will gradually creep up to about 79 kg — assuming the same level of activity.

Likewise, if you pump more heat into a saucepan of water on a hot plate than can evaporate off the surface of the water, then the water will get hotter. It will radiate more heat — which you can feel if you put your hand near, but not on, the surface of the water. If you keep the input energy higher than the radiated energy then the water will just keep getting hotter until it boils.

There are currently four different satellites circling the planet which can measure the difference between the energy hitting their underside — which is radiating out from the surface of the earth — and the energy hitting their topside from the sun. If more energy is hitting the top than the bottom then more energy is going down than is going up and the planet will heat up. It really is that simple. Energy in minus energy out.

Putting a satellite up in space is never simple and always expensive. The first of the four satellites to measure the difference between energy in and energy out was launched back in 1983. Stop and think about that. It takes a long time to design, build and launch such a satellite, and even longer to persuade someone to give you the money to do it. That's how long ago the world's best scientists suspected we had a global warming problem.

Now go back to the saucepan analogy. Suppose the saucepan is made of thin copper and has a lid with a good fit and we just turn the heat on a little. The copper transmits the heat quite well and the pot will boil even at low levels of energy input.

Now imagine a huge cast iron pot about a half an inch thick. Apply the same low level of heat from the hot plate and the temperature rise will be slower and maybe the water won't boil at all — most of the energy will end up heating the pot and not the water.

The difference between the two pots, as it relates to global warming, is summarised in the term "climate sensitivity". The satellites tell us there will be warming, but we don't know whether the earth as a whole is like the copper pot or like the huge cast iron pot. Add the same quantity of heat to the two pots and the final temperature of the cast iron pot will be lower. Note that there are really two things which could be important here — how long will the two pots take to reach their final temperature and what will that temperature be.

4.2 Radiative Forcing

The title of this section sounds like deep scientific jargon. I keep meeting people who are deeply involved with global warming politics, but if I use the word "forcing", I generally notice a blank stare and realise I need to explain the concept. Here is an analogy. We can call anything which tends to change the price of petrol a "cost factor". It could be a tax, it could be the discovery of a new oil field, it could be a fire at a refinery creating a shortage, it could be that an oil tanker is delayed by a storm and you need to pay the crew extra wages etc. Lots of things are cost factors — some raise the price and some lower it.

The term "forcing" is just like "cost factor". The net effect on the planet's temperature is just the difference between the energy arriving from the sun and the energy leaving. Anything which affects this difference is called a *forcing*. Some forcings change the energy arriving at the surface of the earth and some forcings change the energy leaving. Some just move heat from place to place in what seems like a deliberate effort to confuse the hell out of climate modellers.

Our goal is to understand the role of methane (CH_4) in the planet's heat budget. We need to understand this because TWD is a consummate methane generator because of its high red meat and dairy content.

Methane is just one of a number greenhouse gases. These gases make it hard for radiant heat to leave the planet. They act like insulating blankets around the planet. This makes them a forcing. But there are other things, which are not gases, but which nevertheless also impact on the radiation budget. For example, small solid and liquid particles in the atmosphere are called *aerosols* — the same term that is sometimes used for spray cans. They can reflect sunlight coming down to the planet so that a smaller amount arrives at the surface, which stops it heating up — this is a cooling effect. Some aerosols also increase cloud cover which also has a cooling effect. Others aerosols, like the soot generated when you burn trees has a positive (heating) forcing because it prevents heat leaving the planet. When you burn coal in a power station, not only is CO_2 emitted, but aerosols called sulphates are generated which have a cooling impact. In summary, some forcings heat and some forcings cool. You will have guessed that greenhouse gases are forcings, but plenty of things (like aerosols) are forcings without being gases.

Figure 4.1 is a slightly simplified image describing the relative strengths of some important forcings.

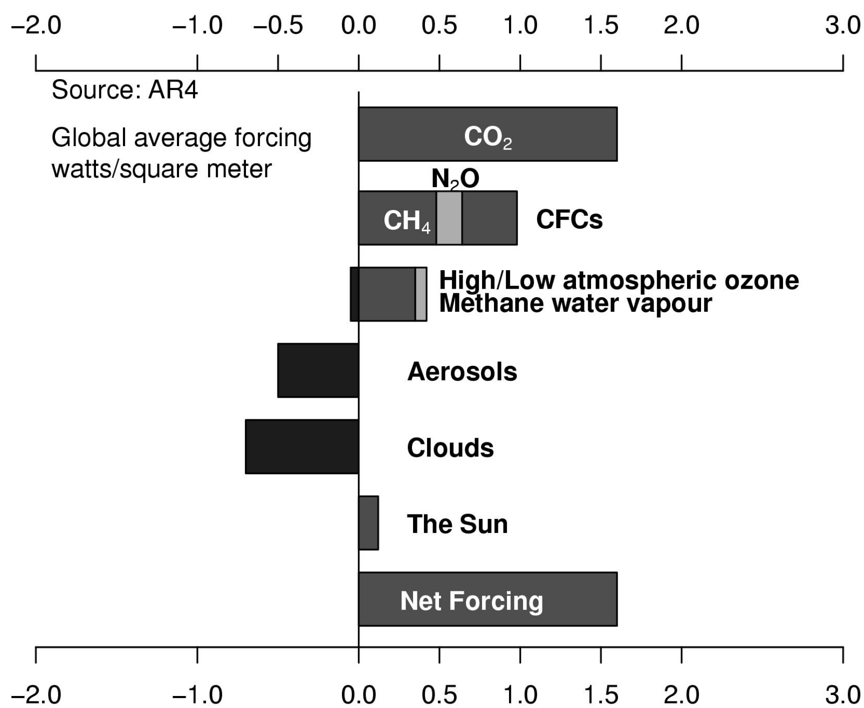

Figure 4.1 Total forcing[50]

The figure is redrawn from the *Summary for Policy Makers* of the latest *Intergovernmental Panel on Climate Change* (IPCC) report. Plenty of people read the summary and plenty more just look at the pictures. This is one of those pictures and it has conditioned the attitude of many people who don't understand exactly what they are looking at.

If you read the accompanying text, this image represents the current forcing due to all human activities since 1750. What does this mean? It means that if farmer Brown chopped down a tree and burned it in 1750, thus creating a little puff of CO_2, then any of that CO_2 that remains in the air is counted and appears in the CO_2 bar in the image. Of course nobody has a clue who burned down how many trees in 1750, but we know exactly how much CO_2 is up in the sky and we know that about 25% of the CO_2 generated from burning trees to make pasture back in 1750 is still up in the air. So the CO_2 bar in this image represents not only *our* climate sins, but also the climate sins of our ancestors going back to 1750. One difference, of course, is that our ancestors didn't understand what they were doing — we do.

What about the CH_4 bar in the image? It's pretty small compared to the CO_2 bar. Because methane is broken down in the atmosphere relatively rapidly, *all* the methane in the atmosphere and represented by the methane bar is, as we have explained, new methane generated in the last 20 or so years. So the CO_2 bar is an accumulated set of sins going back 250 years, but the CH_4 bar is all ours. We made all of that bar!

The net result is that this image, which for many people is the only forcing image they will ever see, is a little misleading. It compares 20 years of accumulating but rapidly turning over methane emissions with over 250 years of accumulating CO_2 emissions. Before moving on, look at the forcing from the sun. Our orbit around the sun isn't fixed but varies ever so slightly so that our distance from the sun and the angle of the line connecting the two poles changes. These changes affect the average energy received from the sun over periods of thousands of years. Similarly, sun spot activity also changes the solar output. The thing to notice is that the average changes in the sun's energy is small relative to the other forcings.

What happens if we look at just our emissions? Our current emissions. The emissions for which we are directly responsible. What does the picture look like then? The full *Climate Change 2007: The Physical Science Basis* (IPCC-2007) report contains precisely such an image, but it is in page 206 of Chapter 2 and rather fewer people will actually read that far. Here it is, Figure 4.2. I've simplified it just a little, but you are welcome to view the original — it's free and available on the web, like everything else that the IPCC does.

Things look very different now, the forcing impact of methane is pretty much the same as CO_2. The actual increase in temperature that *we* are causing today is pretty much equally due to CH_4 and to CO_2.

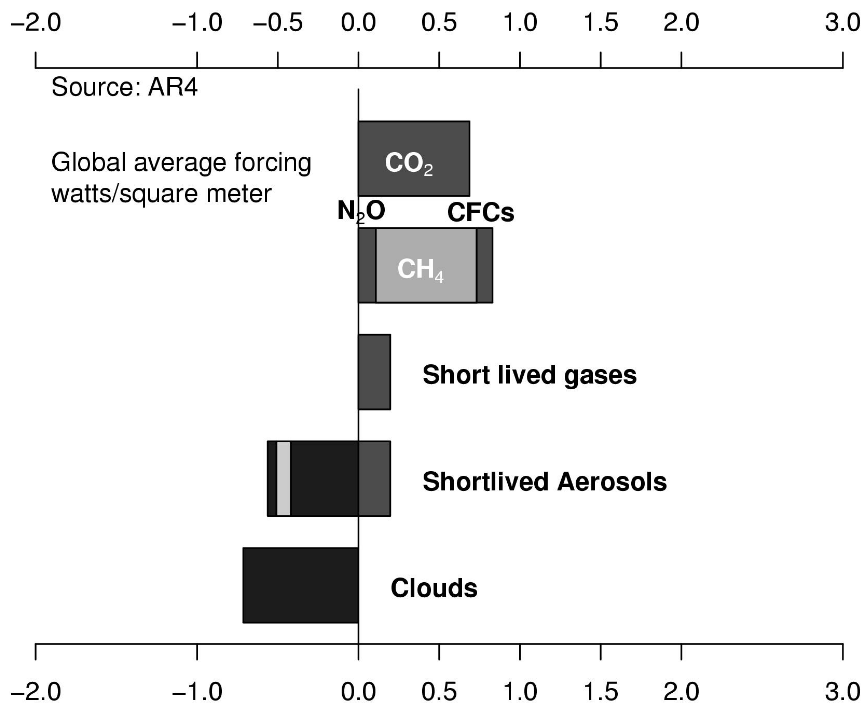

Figure 4.2 20-year impact of 2000 emissions (watts/sq meter) [47, p.206]

4.3 Turning off coal — catch 22

Slowing climate change must involve two overriding activities. First, we aim to leave the atmosphere in good shape for future generations — this is all about CO_2 reductions which will hang around for hundreds of years. Second we need to reduce current warming. We will explain why this is so critical in Section 4.4, but for now just think about stopping the melting of the Greenland and West Antarctic ice sheets that could raise global sea levels by 14 metres.

Achieving both goals is, as I'll explain, equally about CH_4 and CO_2. The aerosols in the figure — which are negative forcings, tend to vanish fairly quickly. For example, when Mount Pinatubo erupted, the aerosol cooling forcing rose markedly, and the global temperature rise paused briefly. But then, in a matter of months, when the dust had settled, the forcing declined. Most of these aerosols are nasty pollutants which kill people, so there are good reasons for reducing them, and we have been — but the rub is that they are mainly negative forcings which cool things down, so reducing them will increase global warming. Soot is an exception, it is always a positive forcing and it also kills about 400,000 people per annum (mainly women and children).[51] No that isn't a misprint. People who cook with wood fires in poorly ventilated huts or houses get cancer and various respiratory diseases.

Forcings add and subtract — just like cost factors. It's hard to compare a storm which knocks down an oil well with a rise in shipping insurance — but both drive costs up and if you convert them to cost factors, then you can just add them together. Similarly with aerosols, gases, deforestation, and the like. Negative ones offset positive ones. It's *net* forcing, not any particular forcing, which heats or cools the planet. Net forcing is like "the bottom line" and ultimately determines if we get hotter or colder. Forcings are measured in W/m^2 (watts per square meter — extra energy hitting each square meter of the planet) just like petrol cost factors are measured in cents per litre.

Coal fired power stations generate two kinds of forcings. Firstly, CO_2, which heats the planet. Secondly, they produce sulphate aerosols which cool the planet. Their net forcing is tricky to measure but may be quite small. It isn't todays CO_2 emissions that are heating the planet, it is the fact that they accumulate. The sulphate aerosols only last a day or two — but since the power plant is running continuously, the aerosol levels stay high. But what would happen if we could, by some miracle, turn off all the coal fired power plants tomorrow? First, you don't add this year's CO_2 increment to the atmosphere, which is great. Second, the negative aerosol forcing disappears in a couple of days. The net result is that the planet will get warmer.

The US National Center for Atmospheric Research has modelled exactly this scenario[52] and the result of turning off the coal fired power stations quickly is a few decades of warming before the CO_2 levels start to drop and things cool down. This warming increase is *in addi-*

tion to the warming that is already in the planet's climate system as we will explain in Section 10.1.

Conversely, because the *net forcing* of all those coal power stations is small, it wasn't actually them which was responsible for the recent and noticeable increase in global temperatures. Here is how it is put by *National Aeronautics and Space Administration* (NASA)'s top climate scientist James Hansen[1]:

> *"The distinction between* CO_2 *and the trace gases is important, because the same activities that produce most of the* CO_2*, burning of fossil fuels and land conversion, also produce aerosols. The net climate forcing by aerosols, direct plus indirect, is almost certainly one of cooling, which would tend to at least partially obscure globally warming due to increasing* CO_2*. Thus I suggest that the sharp global warming trend that began in the 1960s was primarily a consequence of the activities producing the trace gases, mainly CFCs and methane (*CH_4*), as these gases produce only warming.*[53]*"*

This doesn't mean we shouldn't turn off all those power stations, we must. But we must also reduce *net forcing* at the same time — which means we have to reduce those trace gases which Hansen mentions.

4.4 Forcings, feedbacks and tipping points

The concept of *forcing* leads us to the related concepts of "feedbacks" and "tipping points".

Everybody who is overweight or knows someone overweight understands what a feedback is. You eat too much and put on weight, so you feel a little miserable, so you eat more to try and feel better. This doesn't work, of course, you just put on more weight and feel more miserable. This is a positive feedback and it accelerates your weight

[1] Hansen made a brief appearance in Al Gore's film. In 1988 he testified about global warming to Congress. If you want to find out what the global climate is doing today, you could do worse than look at his 1988 predictions. They are chillingly accurate.

gain. The process can work in the other direction, you exercise, lose weight, feel better, exercise more, feel better, lose more weight and so on until some part of your anatomy breaks as a response to all the exercise — ouch.

Climate feedbacks are many. About 30% of all the sunlight hitting the earth is reflected straight back to space. Perhaps by clouds, perhaps by ice. Think about the ice. If any increase in warming melts an unusual amount of ice, then this reduces the amount of sunlight being reflected, so the planet gets warmer, more ice is melted and less sunlight is reflected. This is called the *ice-albedo* feedback. The word *albedo* just means the extent to which things reflect light. Why do white roofs make for cooler houses in hot climates? They reflect more sunlight. Scientists like inventing short accurate ways of saying things — so they say white rooves have higher albedo.

The ice-albedo feedback is relatively simple, others are far more complex. For example, take some soil and heat it up, the microbes that break down organic matter become more active and you can measure the increase in CO_2 as a result of the heat. Globally, this is a positive feedback. The warmer it gets, the more CO_2 is generated by soil microbes, which makes it warmer still.

But if it gets too hot, then the microbes don't function too well and CO_2 production goes down. Quantifying effects like this is a nightmare because of all the different soil types and microbe types. But because the soil holds about 300 times the amount of carbon released annually through burning fossil fuels, it's worth spending a lot of time and effort to try. A 2005 UK study found that increased soil CO_2 production due to increased warming was bigger than all of the emissions saved by the UK between 1990 and 2002 (12.7 million tonnes of carbon per year).[54]

As another feedback, consider a drop in rainfall over the Amazon. If this happens and forest productivity drops, which means CO_2 absorption drops and bingo, we have another positive feedback.

There are negative feedbacks as well. As it gets warmer, some plants grow faster, which mops up CO_2 and acts as a negative feedback. Another negative feedback may be that warming may dry out some water vapour in the upper troposphere, and because water vapour is such a strong greenhouse gas, this could be a strong negative feedback.[55] This is balanced against the positive feedback of more water vapour rising from the oceans of a warmer world.

Believe it or not, climate scientists put all of these feedbacks, and many more into their climate models. This is no different, *in principle*, from an accountant doing a balance sheet working tirelessly to ensure that every account is represented. We need an *"in principle"* in the preceding sentence, because each feedback must be carefully measured by multiple teams before being incorporated and sometimes the measurements aren't available or must wait for both a flash of inspiration about how to measure, followed by weeks of filling out funding applications, and then more weeks, months or years of perhaps turning the brilliant inspiration into a robust result. There will be many failures for each success.

4.5 Greenhouse gas levels

Methane in the atmosphere is measured in parts per *billion*, while CO_2 is measured in parts per million. You can keep track of the levels of these and other gases in the atmosphere at the *US National Oceanic and Atmospheric Administration* (NOAA) website[2]. You will see that methane levels rose sharply during the last half of the twentieth century and then levelled off starting in about 1998.

In 2006 a *Nature* article suggested that the levelling off was temporary and due to drying of natural wetlands and that might just be a temporary respite. In early 2008 came the suggestion that methane may be on the rise again.[56] It will be a couple more years before this is certain, but it is not good news.

Methane levels, until 2008, were sitting near 1786 parts per billion — or 1.786 parts per million. This is about $1/200$th of the 384 parts per million level of CO_2, but it is having about half the impact[46] – which is a rough way of demonstrating that it is about 100 times more potent[3].

[2] `http://www.noaanews.noaa.gov/gmd/aggi`

[3] The figure of 72 we have used elsewhere in this book is averaged over 20 years and is the official IPCC figure.

4.6 Australia's livestock blowtorch

Hold a blowtorch a few inches from your leg for just 10 seconds. It will cut to the bone instantly. Will your agony diminish if I tell you that the temperature, averaged over 20 minutes, is just 48°C? I don't think so. Under international rules (the Kyoto Protocol), different greenhouse gases are compared and added together by averaging their impacts over 100 years — regardless of the time it takes any particular gas to break down and become ineffective as a greenhouse gas. Averaged over 100 years a tonne of methane has 21 times the warming of a tonne of CO_2 — so in our greenhouse gas inventories, one tonne of methane appears as 21 tonnes of $CO_2^{\mathbf{eq}}$ (carbon dioxide equivalents).

This is like equating a 10 second blow torch exposure to a 20 minute exposure with a 48°C candle because the average temperature of both over 20 minutes is the same.

The principle would be fine if all gases took the same time to break down and if we had a hundred years to deal with global warming, but they don't and we don't. A tonne of methane breaks down quickly but has an actual warming over 20 years that is not 21, but 72 times greater than a tonne of CO_2.[47] The next 20 years may well be crucial for deciding the climate of the our children's children, so why the Kyoto negotiators chose a 100 year averaging period is a mystery. But this Kyoto factor of 21 for methane must be music to *Meat and Livestock Australia* (MLA)'s ears because it massively underestimates the global warming caused by its industry.

The *Department of Climate Change* (DCC) is responsible for measuring greenhouse gas emissions in Australia. During the past decade[57] they generally put the methane output of our livestock at about 3 million tonnes per annum. The actual warming produced by this methane is equivalent to $72 \times 3 = 216$ million tonnes of CO_2. Our coal fired power stations produce about 180 million tonnes of CO_2 each year, but they also produce sulphate aerosols with a negative forcing that isn't measured. In any event, the *net* forcing of the power plants is significantly lower than 180 million tonnes.

Nothing in the above is disputed by the IPCC or any climate scientist, so why is CSIRO, via the TWD, favouring foods, red meat and dairy products, that generate more warming than all of Australia's coal fired power stations? Are some in the top echelons of CSIRO secret climate change skeptics? What other explanation is possible?

The same DCC annual inventories also estimate that personal motor vehicles generate about 43 million tonnes of CO_2. So our livestock generated 5 times more warming than our cars.

Nevertheless, despite the red meat industries being our biggest climate forcing, despite the fact that methane reduction is absolutely necessary to any strategy to slow warming of the planet in the short to medium term (20-50 years)[46] and despite the IPCC telling people to "please eat less meat", when we examine official Australian advice about global warming later in the book, we will find that advice to cut meat consumption is rare among green groups and absolutely absent from the Federal Government and most State Government websites.

The climate forcing from livestock has many components. We have dealt with methane from the digestion of food in the animal's guts. But there are other elements. Consider, as just a small example, sheep and cattle excrement. What happens when sheep and cattle deposit faeces and urine in a paddock? There is plenty of complex chemistry here, probably nitrous oxide release being the most significant — nitrous oxide is even worse than methane. The DCC calculates that urine and faeces deposited in paddocks releases about 4.3 million tonnes of $CO_2^{\mathbf{eq}}$ per annum.

Australia has one of the highest ratios of cattle to people on the planet, but even in countries with fewer cattle per head of population, the emissions involved in the meat production chain still far exceed anything possible from a plant based diet and generally exceed transport emissions.[58] It also surprises most people to find that grass-fed cattle, according to CSIRO researchers, can generate 2 to 3 times more methane than cattle fed on grains in feed-lots.[59] This is one example where the inhumane and artificial has climate advantages over the "natural".

In the next chapter we return to nutrition again. We look at the mythology surrounding red meat and do some serious myth busting.