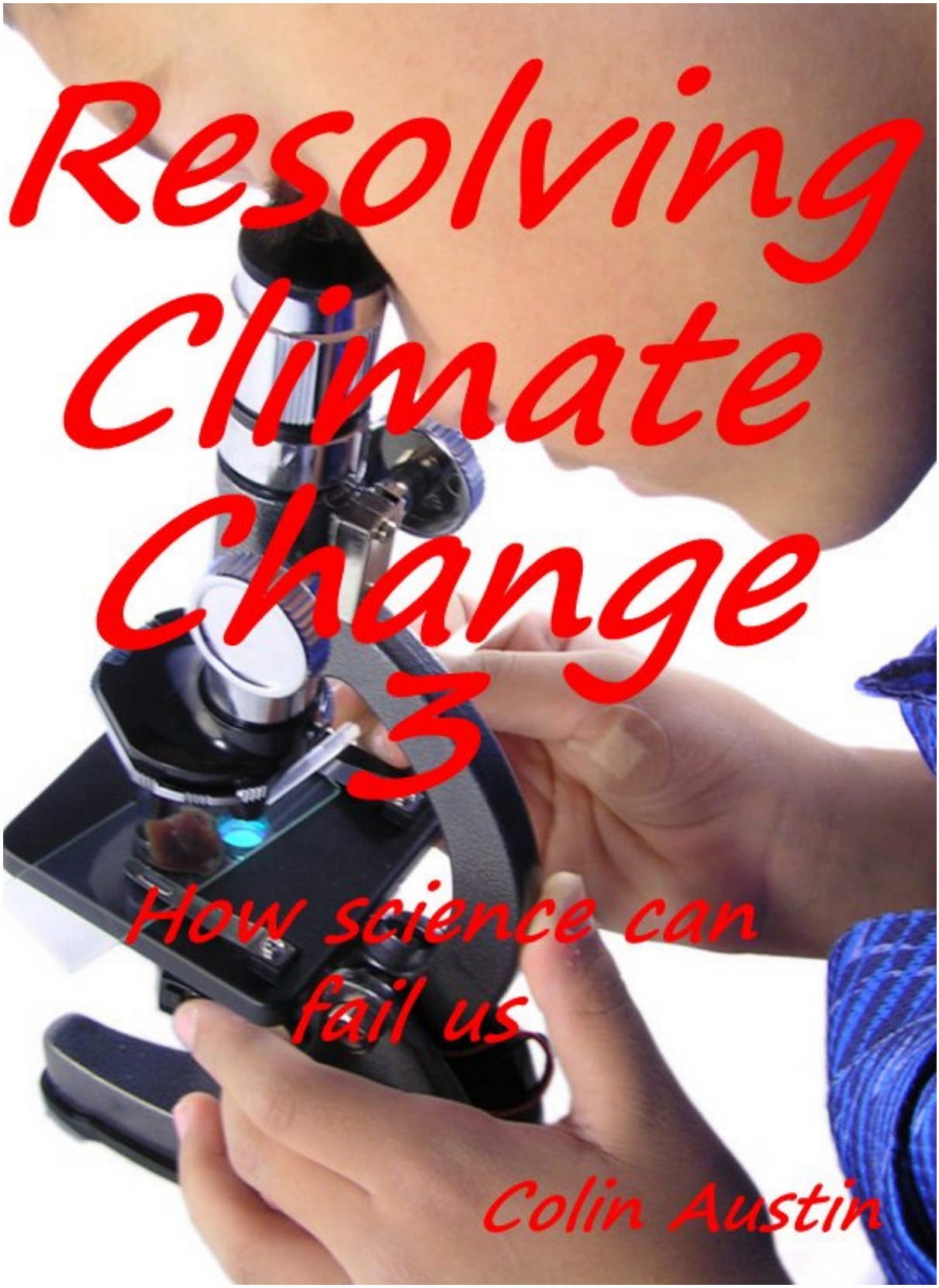
Resolving
Climate
Change
3
How science can
fail us
Colin Austin

Resolving Climate Change 3

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How science can fail us

Colin Austin 11 Sep 2012

Prologue - Don’t get me wrong

Don’t think for a moment that with a title like ‘How science can fail us’ that this is a climate deniers delight. It’s exactly the opposite - climate change is real and happening now, - it is about how the reductionist approach of modern science is hindering finding solutions to climate change and how the speculative approach of the innovator can provide solutions.

climate change, soil, carbon, science, innovation, greenhouse, sequestration

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Contents

About The Author

Colin Austin has had a varied career after graduating in engineering in from Sheffield University in 1963. He started his career in process control, gradually building up expertise in the control of plastics processing equipment, working as R & D Manager before taking a spell in academia lecturing at RMIT in Melbourne.

Some years ago, Colin wrote a piece of software that transformed the international design of plastics molds using scientific principles rather than 'gut feel'. So successful was this software that the company that Colin founded (Moldflow) became the largest exporter of technical software in Australia, a multi-million dollar company selling in over 48 countries throughout the world. He attributed the success to the system of speculative research he used to create innovations.

He became increasingly concerned about environmental issues, particularly the management of what he sees as the world's most critical resources soil and fresh water. Just as he had changed the plastics industry from a 'hunch based' to a science based process, he saw that soil and water technology could be transformed by the application of the scientific approach.

He realized that the work he had being doing on improving soil by increasing the organic content could have profound impact on resolving climate change.

He authored the companion books Resolving Climate Change 1 and 2, also available on Kindle.

Resolving Climate Change 3 How science can fail us

Don't get me wrong

Don't think for a moment that with a title like 'How science can fail us' that this is a climate deniers delight. It's exactly the opposite - climate change is real and happening now, - it is about how the reductionist approach of modern science is hindering finding solutions to climate change and how the speculative approach of the innovator can provide solutions.

I should want to talk about solutions to climate change - not whether it exists. But I am so bottled up about the lousy job science is doing on convincing people that climate change is real that I have to get it off my chest.

English is full of phrases that mean the exact opposite of what is said. People say I don't mean to - interrupt - be rude - hold you up - or whatever then immediately interrupts you - be rude to you - and hold you up. So I don't mean to talk about whether climate change is real - but I can't stop myself.

The Age of spin

What Joe Public sees is a mass of totally confusing and detailed data which is unintelligible and unconvincing.

What scientist and propagandist miss is that we live in an age of spin, and people have become immune to it, like chicken pox or measles they have developed an immunity against it. The classic approach of the spinner is to present a whole series of facts which are undoubtedly true and which the listener will agree with, then the spinner hits with a punch line which is nothing to do with the previous lists of facts.

'Roses are red, violets are blue'. These are facts which most people will accept, the pedantic may argue that roses aren't always red and that you can grow violets in an acid soil when they may not be totally blue but most people will give these statements a thumbs up.

But the next line of this little sonnet *'and I love you'* bears absolutely no relation to the colours of various flowers. If I hear one more sceptic say that we had bigger rains, longer droughts or that in Romans times they grew grapes in the north of England I will have an acute attack of the screaming abjabs. What they are saying about previous climates may be demonstrably true but is absolutely nothing to do with whether greenhouses gases are warming the earth.

The world of spin is full of these strings of facts followed by a conclusion which bears no relation to the string of facts. I call this foffle, facts which are really woffle. The world of climate change is full of foffle, put out by both sides of the debate, which are totally unconvincing. A bunch of facts is not the same as truth, so how do we get to the truth.

Long, long ago in my student days I discovered I had certain mental deficiencies - I had a very bad memory and my mind would wonder of so I did not pay attention. These are not good characteristics for a budding student. These have stayed with me and I have had to find a work around.

I love to watch science shows on TV. For some reason producers of science shows think that it is essential to have an extremely attractive presenter, invariably I find that I have been ogling the presenter rather than listen to what she said. This I can resolve by recording the programs and rewinding when I find my mind had wondered off. Often I wonder what ever happened to Karina Kelly, the undoubted queen of science shows, has she moved onto that land where presenters and Virgin flight attendants go to when some bean counter thinks they can improve rating by introducing a newer and younger face.

But serendipity came to my aid when I had a maths teacher who pronounced that you could write all the formulae you need to solve mechanics problems on the back of a post card. Forget about all those long equations you are expected to remember - everything can be derived from a few simple formulae, Newtons laws of motion, Young's law of elasticity, the heat transfer equations, conservation of mass and energy etc.

All you had to do was remember these basic formulae - understand the basic principles or the underlying essence and you could still get a reasonable degree. But it taught me - an absent minded ogler - a valuable skill - getting to the essence.

The essence of climate change

Arguments of climate change cannot be won by foffle. There is no point in tabling pages of data showing masses of temperature rainfall data, the sceptics will always find an alternative set of data which 'proves' what they want - we need to get to the essence.

It was Joseph Fourier, in 1824 who smelt a rat. Nowadays we are used to scientific instruments which have been computerised and miniaturised that it seems too much like magic. So I am going back to a primitive instrument that anyone can understand or even make themselves. Climate change is all about radiation, or rather the energy in radiation.

We need a way of measuring the energy in radiation. Just get a brick, lump of iron or block of something or other, paint it black and put a thermometer into it. Wrap it up in a blanket except for one face. Now point at the sun and it will get hot. Simply measuring the temperature rise over time tells us how much heat is coming from the sun.

Now if we turn the block upside down we can measure the amount of radiation the earth is emitting back into the atmosphere. Of course Fourier had to allow for the fact that the earth is continuously radiating it energy back into space over 360 degrees while the sun's rays strike the earth at an angle which changes throughout the day.

Now at equilibrium the amount of energy striking the earth should balance the amount of energy being emitted by the earth or otherwise the earth would be heating up or cooling down. Fourier found that they did not balance and predicted that the earth would have to be below freezing for balance, from which he deduced an insulating layer in the atmosphere.

In simple terms the sun is high energy radiation which has no problems in blasting through the earth's atmosphere, the energy being radiated from the earth is low energy so energy is absorbed by the atmosphere. That is the basic physics of a greenhouse gas.

Svante Arrhenius took this further and based on measurements of the amount of heat absorbed by carbon dioxide calculated a total heat balance for the earth. Since then we have been measuring the increase in the amount of carbon dioxide in the atmosphere which means that more heat is arriving on the earth than is being lost by radiation. A climate denier may argue that this is just theory - but there is hard evidence of the heat imbalance.

It is always a god strategy in trying to put a convincing argument to refer to a common effect which people can relate too. Everyone has experiences that in winter a clear night with no clouds is much colder than an overcast sky with lots of clouds. Water vapour is an extremely effective greenhouse gas and provides excellent insulation. Even an extreme sceptic would have problems denying that simple observation.

Using satellites we have been measuring the amount of energy falling on the earth by the sun and the amount of energy being radiated by the earth back into space, the excess energy falling on the earth has been described in terms of multiple Hiroshima bombs per minutes. Now this may be a way of trying to convert the sceptics but is not answering their objections.

There are bands of climate change deniers who prowl the internet looking for ways of hurling abuse at those who champion the need for action on climate change. Put simply these are nutters who will never be convinced by any argument. The people we need to convince are the politicians, particularly the right wingers in the US and more importantly the people who vote for them, who are effectively blocking real action on climate change.

Every day I look at my Google alerts on climate change which shows both sides of the argument. The more rational of these politically powerful climate deniers are not simply denying the world is warming, they accept that the earth is warming but they dispute that it is as bad as is made out and that it is simply not worth making major sacrifices to avoid a slight warming.

But science (or at least the Governments who promote action on climate change) is not making the key information available to the public. We need two very critical pieces of information which are 1) how much the earth will warm for increased levels of greenhouses gases and 2) how long will it take.

Let us look at a simple case of an excess of energy - what happens when we boil a kettle. Before we switch on the power there is an energy balance - the kettle just stays at room temperature. We switch on the power and put our hands around the outside of the kettle, what do we feel? At first absolutely nothing. Even if we had super sensitive instruments they would show no instantaneous temperature rise.

Then gradually the heat soaks through and we feel the temperature rise, we don't need any flash instruments we can feel it getting hot. This is exactly what happened with global warming when we first started to use steam engines, at first there was absolutely no effect. The earth is bigger than a kettle and it takes time to get hot.

If we don't have a thermal cut our on our kettle it will boil until all the water has gone, then it will get seriously hot until the heat loss from the dull red glowing kettle balances the energy input and we have reached equilibrium - or more likely it blows up (ps make sure you have paid you fire insurance).

For us living on the face of the earth wanting to take a sensible decision about climate change we need to know how hot the earth will get. The work of Fourier and Arrhenius indicates that the traditional level of greenhouses gases raised the temperature some 20℃ making the earth habitable, but they tell us that simply doubling the green houses levels would increase temperature by only a further 5 degrees, this indicates it is highly nonlinear.

Again this makes sense with a simple analogy, using two bed quilts does not make you twice as hot.

Joe Public wants to take an intelligent view of climate change. For this he needs to know what the new equilibrium temperature will be for any level of greenhouse gasses. But where is the magic graph which shows the predicted equilibrium temperature against greenhouse gas levels?

Clearly a vital piece of information to have an intelligent view on climate change, one which is almost certainly available to climate scientists but does not appear in any publication available to the public.

The next critical question is how quickly the earth will heat. We may know the excess energy for different levels of greenhouse gases but again this information does not seem to be available to the public. Now I spent a lot of my life on heat transfer and I know it is a relatively simple calculation to predict the rate of temperature rise over time. Of course it is an exponentially decaying function with the temperature gradually reaching equilibrium at an ever slowing rate. But people are very familiar with the half-life concept, so why hasn't some organisation made this information available to the public.

It totally amazes me that in Australia, my home country that the Government has gone ahead with a highly controversial carbon tax cum trading scheme with so little explanation of the basic information needed for intelligent assessment. The level of information is appropriate to a kindergarten, not a reasonably well informed public. You don't win votes by treating the public like idiots, we may not all be climate scientist but most of us have fixed cars and lawnmowers and have a basic knowledge of how things work. Understanding how a kettle boils is not rocket science.

Of course part of the problem is the way science information is published. Every scientist wants to get his paper published by the prestigious science magazines like Science and Nature, getting published is the way to get the next grant. Joe Public can easily find out about the article from his friend Mr Google which will give him the abstract but if he wants to go and read that article he will have to fork out some $20. Now $20 is not a big deal for one article but Mr Google lists many important articles on climate change, I get about 20 per day from my search. Joe public is simply not going to pay $400 per day just so he is informed.

This is a form of information black mail; the original work was almost certainly paid for by the Government from Joe's taxes but now he is effectively prohibited from accessing that information by a money barrier. This is a very bad situation. Publically funded research on public issues should be available to the public.

Well I didn't mean to talk about whether climate change is real or not - but I have and now I feel a lot better and can get on with what I really set out to do, which is talk about how science is failing us in coming up with strategies for managing climate change.

Part 2 Solutions to climate change

The trap

The classic reductionist scientific approach can fail to provide the solution to climate change.

Modern science is what we call reductionist, which means there is so much to know that it is impossible for any one person to study everything about everything so they specialise in some narrow niche and become an expert in that particular bit of science. It is like going down a funnel, getting more and more intense as you go down the funnel. It is the only way science can work in this highly complex modern world we live in.

Reductionist science has given us a staggering knowledge and improvement in our standard of living, now one doubts that it works, the other side of the coin is that we end up with a mass of separate little pocket of knowledge which until they are put together don't realise their potential or even lead to conclusion which are simply incorrect and this is where often where things go wrong.

The great power of science is the development of a general law. We look at individual experiments and look for a pattern, we can then test this pattern to make predictions and if they are consistently correct we have a useful general law. Newton no doubt did experiments with accelerating masses, (or at least looked at Galileo's experiments). It is fine to put a lawn mower engine into a giant truck and find that it accelerates pretty slowly and then put a jet engine into a go cart and find that it accelerates at an incredible rate until it explodes and kills you.

Newton's genius was in describing this in a simple general law which was applicable to all conditions that existed in his day. Apart from those involved with space travel these basic laws still provide us with the basis of modern technology.

This process of integrating together multiple pieces of science is just as important as discovering the information in the first place. I learned this lesson many years ago when I first developed the Moldlfow technology. This involved putting together many pieces of technology into a system, no doubt the specialist working in there were far smarter than me but none of the working in their niche area of technology came up with a working solution.

I studied these separate bits of science as best I could, and integrated them into a working system. I often found myself reading multiple coupled partial differential equations which I really did not understand, however I found that by going back to first principles, looking at the forces acting on little blocks to develop the computer software gave the solution.

This integration is the exact opposite of the reductionist approach. The really great pieces of science lead to general laws which can be widely applied. This integration is where things tend to go wrong in science.

The grand plan

The argument I want to develop is simple. I accept that climate change is real and the resulting extreme weather, floods and droughts, will cause major harm. The cost of extreme weather has been calculates at 1.2 trillion dollars.

In the long term there is no option but to reduce a use of fossil fuels, there is an abundance of net renewable energy available but it is often not available when needed. Until such time as a practical way of storing energy is developed we will remain dependent on fossil fuel. But new technology tends to appear from unexpected sources by serendipity. We need time to let this new technology appear.

Storing carbon in the soil will buy us a window of opportunity for this discovery of the new technology to appear. A major program of storing carbon in the soil would give us a breathing space of some fifty years.

Early experiments with reductionist science and soil regeneration

I felt that at some time the destruction of our soils would be a critical issue for mankind. When I first started my experiments on soil regeneration - some forty years ago, before I really understood about the systems approach - I tried to use the techniques of science in which I had been trained.

Then this was little more than a hobby. I owned a small farm with totally degraded soil - little more than bare clay. In my early experiments I tested as many soil regeneration methods as I could find, such as gypsum, sulfur based clay breakers, seaweed extracts, fish oil, deep ripping, rotary hoeing, green manures of legumes and oats etc. I followed the classic scientific approach, only changing one variable at a time and comparing with reference sites.

The results can only be described as a total failure, none of the methods made any real impact on the heavy clay. The results were also inconsistent between the same treatments on different test patches; even though the field appeared uniform there was significant variation over the test patches.

Much later this was explained to me; - in a dry period the clay cracks, these cracks become partially filled with wind-blown debris. When the rain comes the clay tries to expand but the cracks are filled so large pressures are developed which force virgin clay from deep in the ground toward the surface creating a variable soil pattern.

Multi variable systems

I decided that there was no one solution to soil regeneration but a variety of techniques had to be used in combination. But how was I to carry out scientific tests with so many variables? The truth is that the classic reductionist approach of science, studying every aspect in detail to gain an insight into how each variable works is simply not effective with complex environments. This is the classic problem of multi variables which has frustrated scientist for many years. The Taguchi method is one of the few systems developed to research multi variable but I failed to make it work with regenerating soil.

I felt I needed to adopt a different approach looking at the process as a system, focusing on the overall performance rather than the individual components. It is a bit like cooking; understanding in great detail all the ingredients does not make a good cook, what matters is how they are combined together.

I saw that the systems approach was the only way to tackle soil regeneration. The first step is to get a system that works, however badly, then gradually refine this method.

The single variable approach can lead to dangerous conclusions

Let me take just one example of how good science can lead to very dangerous wrong conclusion. Let us assume that our political leaders read the quality scientific report 'Arbuscular Mycorrhizal Fungi Increase Organic Carbon Decomposition under Elevated CO2' by Lei Cheng1 published in the reputable publication Science. They did very detailed experiments and found that increasing atmospheric carbon dioxide actually increased the rate of decomposition and the release of further carbon dioxide into the atmosphere.

This is an experimental result of a well conducted trial and therefore we can have a high confidence that this is true. This is going to the bottom of the funnel. But then they then go up the funnel to make a general conclusion that storing carbon in the soil is not a viable tool against climate change. This is what was widely reported in the popular press which is likely to be read by politicians and policy makers.

This would be disastrous. It could lead to the politicians abandoning the one solution to climate change which is easy and practical to implement. This is so important we need to examine the process, not just the specifics of this particular case which I am using as an example of the process of science.

The reductionist science behind their paper which received widespread publicity is sound. They did a number of tests under carefully controlled conditions and found that increased carbon dioxide in the atmosphere led to high rate of decomposition and an increase in the return of carbon dioxide to the atmosphere. This was the results of carefully controlled experiments and we can take as valid.

However the danger comes in the reverse process of integration trying to generalise the results. What matters is not the rate of decomposition, which may well be faster than with lower carbon dioxide levels but the residual amount of carbon retained in the soil at the end of decomposition.

Just because the rate of decomposition is faster it does not mean that the final carbon remaining in the soil will be less, it could be that the equilibrium level is reached quicker. But there is a wider issue, in any scientific experiment the designer of the experiment tries to keep all variables under control except the variable under investigation. With soils we are dealing with a complex combination of multiple variables all of which interact.

For example the increasing the concentration of atmospheric carbon dioxide will also increase the metabolic rate of the plants e.g. the plants will absorb more carbon so we may be simply looking at a system which works faster, with more carbon being captured and more carbon being released.

But if I understand correctly, the tests only lasted for ten weeks and there appears to be an assumption that this increased rate of decomposition will continue so overall there will be more carbon dioxide emitted with the increased level of atmospheric carbon dioxide.

But it could simply be that the increased rate of decomposition continues faster and reaches the stable level in a shorter time in which case the increased atmospheric carbon dioxide level has had no effect on the stable carbon sequestered. It could also be that the amount of

organic material added to the soil from crop residues etc. could actually be higher at the end of a longer period.

But the critical question is - can we change agricultural procedures as a whole to capture more carbon in the soil. The answer to that question is yes, but we should adopt the systems approach to refine the changes needed to the agricultural procedures.

It would be a tragedy if the finding of this research led to the conclusion by policy makers that soil carbon cannot help resolve climate change. Widespread adoption of soil carbon farming thorough the world may be the one opportunity we have to avoid the hazards of climate change.

So where does this leave us. It is possible to conduct good science, using carefully controlled experiments and come to conclusion which are valid in the strict scientific context in which they are conducted but lead to the wrong decision when acted on by the political system.

The systems approach to soil regeneration

The fact is that using a fully integrated soil regeneration system it is possible to sequester large amounts of carbon into the soil. This is easiest and may be the only option to combat climate change in the short term. It gives us a breathing space while alternatives to fossil fuels are developed.

The weakness of reductionist science is in developing a general law from a few specific tests. We have to look at the system as a whole not just one particular aspect. This is the difficulty of dealing with a multi variable system. There is little doubt that mycorrhizal fungi will increase the carbon retained which is the key to resolving climate change.

Failures of climate change policy

The unpleasant reality is that we (meaning humanity in general but our scientists, engineers and political leaders in particular) have failed to come up with a viable solution to climate change; we (the world) are emitting greenhouse gases at an increasing rate. It would be wrong to think of soil carbon as a permanent solution. With the currently available technology there is certainly capacity in the soil to absorb carbon for fifty years which give us a breathing space, time to come up with a permanent solution.

Timing can be crucial, let me give a couple of examples from history of previous ecological disasters, which were avoided by serendipity. This process of serendipity may appear at first sight to be a very poor strategy. But using soil carbon to give us a break to find a solution of burning fossil fuels is a very practical approach based on the nature of the development of new technologies.

I call this the serendipity approach.

Britain and the oak trees

A few centuries ago Britain was busy cutting down its vast forest of oak trees to build war ships. The French and Spaniards were similarly cutting down their forests - obliging the British by providing ships for them to sink.

No doubt there was panic amongst the British leaders as it become obvious that the oak trees were rapidly running out. This would leave the British, (and the French and Spaniards) at the mercy of the frugal Dutch who had been carefully staying out of the war preserving their powerful Navy and supply of timber.

No doubt the leaders were considering all immediately apparent solutions - such as oak plantations, and wishing they had they had genetic technology to develop fast growing oak trees but at that time it took a hundred years to grow an oak.

So what was there solution? There wasn't one - like us with climate change, they simply did not have a simple and obvious solution. They were heading for ecological disaster, rather analogous to the natives of Easter Island who at that time had cut down all their trees and were progressing through the stages of first eating their children to all out cannibalism. (I wanted to put that in to show that ecological disaster is not a pretty sight - as the inhabitants of Sudan, suffering from starvation from climate change, well know.)

But the day was saved by some unknown engineer (who escaped the history books) who perfected the art of rolling steel sheet, which made far better war ships and allowed the fighting to continue. This was simply an out of the blue, serendipity event which saved the oak trees and what was left of the English countryside.

Horse dung in New York

The second example of serendipity at work I want to use is that of the embattled mayor of New York at the beginning of the last century. His city was sinking under a tide of horse effluent and no solution seemed in sight. But again serendipity was at work, the car and mass production came along replacing the horse drawn wagon and the problem of horse effluent was solved.

Serendipity and climate change

How does this relate to climate change? Burning fossil fuels is the core of the problem with climate change and at this moment there is no viable alternative.

The issue is not a shortage of alternative energies but control of that energy. Theoretically we could readily generate all the energy we need from alternative sources, solar, wind, waves etc. But they lack the control of fossil fuels.

Think about the masterpieces of technology that the modern automotive industry has developed. From standstill you can press a pedal which will release hundreds of kilowatts of power which will accelerate the popular SUV, a pseudo military vehicle to 100 kph in well under ten seconds and equally important turn off the power when required.

It is not just the internal combustion engine. There is an amusing documentary put out by the BBC showing the antics at a power station at the day of the cup final. As soon as the match is finished there is an anticipated sudden demand of power as everyone rushes to put the kettle on, but they do not know precisely when. The sketch shows the top executives anxiously sitting around the television screen waiting to see if there is extra time. When the match is appears to be almost over the bosses give the order to bring the stand-by turbines up to speed, (which takes a couple of minutes), before the demand for power surges.

Storing energy

We could solve climate change right now if we had some magic device which could temporally store and release energy to balance supply and demand. But no such device appears to exist (as yet). What will it look like when it comes, will it be some monster battery using salt water as an electrolyte, will it be some giant space structure reflecting energy to earth which is used to generate liquid fuel, will it be some giant algae farm in the sea converting the carbon absorbed in the sea into a feed stock to make oil?

Probably none of the above, more likely something out of the blue, some poor scientist working some remote part of the world working out how a crocodile can stay still for hours on end then suddenly release energy equivalent to that of the pseudo military vehicle. He sends his report back to base and on his return finds he has been awarded the Nobel peace prize for solving climate change - but his wife and children have left him for desertion.

Or maybe it's some marine biologist working out how the electric eel stores its energy. Now I am not suggesting that having thousands of tanks full of electric eels is the way to store bulk energy to drive our modern economy, I am just making the point that the history of new technologies is that they come out from left field without warning.

Here and now

It is certain that the new technology, whatever form it takes, will not occur quickly enough to offset the effects of climate change, such as the increase in the severity and frequency of floods and droughts. These are here and now problems which soil carbon can ameliorate.

Improving soil sequestration of carbon will also increase agricultural production and food security so people do not starve. It is a simple and practical technology which can be implemented immediately. It can ward off the effects of climate change while alternative energy technologies emerge.

So why is it so difficult to get a global climate change policy implemented - it is the action of the sceptics and for that I have to talk about the tooth fairy.

The tooth fairy and climate change

Children, at some point in their development reach a point where they begin to suspect that their parent are guilty of the most despicable con tricks on their offspring. I was found out, one night, when trying to sneak a twenty cents coin under the pillow of my daughter. Gone was the myth of the tooth fairy, it was just dad tricking me into stopping crying.

Anxious to explore what other damage had been done I asked her whether she still believed in Farther Christmas. This brought on a long pause which was broken by revealing the secret of why it is so difficult to get action on climate change and the psychology of mankind in adversity.

Daddy – she said – if I stopped believing in Farther Christmas would I still get presents?

Now let's face reality, which is more fun, to gun a pseudo military vehicle up to 100 kph and then screech to a halt at the next traffic lights or to adopt an Ashram type existence, living in a cave, wearing a goat skin shirt and eating raw cockroaches. People being people are going to be deniers until some viable and acceptable plan is presented to them.

No contest - no wonder it is so difficult to get action on climate change.

Soil carbon may be neither the ideal or long term solution but it holds the wolf from the door. So what are the problems?

Science and innovation

The debate on soil carbon can be euphemistically called heated with some soil scientist putting forward highly technical arguments saying that the amount of carbon that the soil can store is limited while other put forward equally technical arguments saying it can.

To reach a view it is best to look at how science and innovation work together.

So far I have been a bit flippant in my presentation but now I want to get to the core of how, when it comes critical issues, like climate change, that the strict scientific process may not deliver the goods. For this I need to establish some technical credibility.

I see my role as a technical innovator; - I have had to study how science and innovation work together. I founded and built up a company which became Australia's leading exporter of technical software based on these principles of innovation I want to describe here.

We were a small Australian company supplying technology to major corporations around the world. Technology is a difficult business because new technology rapidly becomes the old so I was faced with the problem of how to bring out new and innovative products every three years, about the life cycle of a software product.

Our customers were much better equipped and financed than we were. We survived by having a clear understanding of how science and innovation work together. It is useful to have an analogy between reductionist science and a complex machine such as a modern car. This is made of thousands of components which someone has worked on and studied in great detail. This is analogous to a reductionist scientist.

But someone has to work out how to put all these working components together to make a car; this is analogous to an innovator.

This is how reductionist science works. Around the world there are thousands of scientists busy working away on their particular specialty. No one knows more about their highly specialist area than they do.

There is a widespread (but often wrong) view that innovative products comes from some scientific breakthrough. True - there are some classic cases of a science breakthrough leading to new technologies, the transistor and atomic energy are classic examples. But this is not the way innovation normally occurs. Innovators must clearly understand the problem to be solved. They then search science looking for components which can be integrated together to produce the innovative product.

The Apple I-phone is a classic example of innovation at work. It did not come from some new scientific discovery but the simple realization that most people who bought a mobile phone had little idea how to operate it, particularly after the initial enthusiasm had worn off and they had lost the operating manual. Apple saw the problem and integrated a range of existing technologies into the phenomena we call the I-phone.

Once the innovators have a working system reductionist science can study the components to make the system work better.

The steam engine was not developed because Carnot developed the thermodynamic theory. Early steam pioneers like Thomas Savery, Thomas Newcomen and James Watt created the first primitive and inefficient steam engines based on guess work and hunch. Carnot saw the importance of steam power and developed the theory of thermodynamics which lead to major improvements in efficiency and really started the steam age.

This story is repeated throughout the history of technology, neither the empirical approach or reductionist science is effective by itself – success is achieved when they work together.

I recruited top ranking University graduates with first class honors and Ph. D's to develop these new products. These were very well trained in the scientific process, well versed in the reductionist approach of modern science and knew exactly how to conduct controlled experiments.

They had been trained to be careful and cautious, making sure their results were sound and which would lead to high quality papers which will be approved by their peers. They never wanted to go out on a limb.

Science is concerned with discovering fundamental truths and being precise and truthful is an essential part of their training. Engineers have a totally different view on errors and ignorance. The build machines and structures never properly understanding every aspect. They handle this by the use of what they call safety factors. This is about the only time I know of that engineers have shown any skill in public relations because they are not safety factors at all, they are ignorance factors, they simply do not know how strong their structure will be so they estimate their level of ignorance and simply make things a bit stronger based on that level of ignorance.

An interesting point to contemplate while flying at ten thousand feet.

My new recruits, although very bright and trained in the scientific method, were simply not producing the innovative new products needed to stay ahead. I needed to train them in how to be innovative and adopt the systems approach. The systems approach means putting together a total system, even if not very good and gradual refining this by thinking about the system as a whole and not worrying if some details are not really understood.

I had to retrain them to understand that innovation involves risk, and risk means many failures, initial failure is normal in innovation. I had to show them that is did not matter how many times they failed; what mattered was finally producing an innovative product.

When considering whether soil can hold the needed volume of carbon it is important to ask the right question. There is a great deal of research looking at how much carbon is stored (or lost) by conventional agriculture. This will not give us the answer we want. First we should look at ways we can change agriculture to store carbon, then we can ask how much carbon the soil can hold.

Unfortunately in the debate on soil carbon the soil specialist tend to look at how much carbon is being stored with current agricultural methods. Ask the wrong question and you get the wrong answer.

Missing the obvious, Soil – can it really store bulk carbon

Soil has the capacity to hold large amounts of carbon. Storing carbon deep in the soil it can hold enough to keep greenhouse gases at bay for fifty years. This can be shown by a simple calculation based on available land area and how much carbon it can hold per unit area.

Vegetation is already extracting large amounts of carbon from the atmosphere - some thirty times all man made emissions and there is no problem in getting this into the soil to form a mixture.

But - and this is the heart of the problem - the amount of carbon escaping from the soil is very near to the amount captured by plants. The challenge is to get the carbon into the soil so it stays there and does not go back to the atmosphere as carbon dioxide.

There are some soil scientists who are sceptical about the soils ability to capture and store carbon. Typically they look at current agricultural systems rather than what could be achieved by changing the system.

For example they measure the soil carbon with say no till farming and come to the conclusion that the increase in soil carbon in minimal. This may be an experimental fact. However this is because the crop residues are left of the surface where they will rapidly oxidise. It only take a small change, adding specific breeds of deep burrowing worms which will come to the surface at night and drag the crop residue deep into the soil where is will be converted to humus, to significantly increasing soil carbon.

This is the essence of the systems approach, looking at the overall effect and not focusing on highly specific details.

What Joe Public thinks

Now Joe's life has been dramatically changed. At one time he had very little access to information other than the newspaper and the TV. Now Mr Google has changed all that, he now has access to a deluge of information, almost certainly too much to sift through every piece of information and come to a valid conclusion.

He probably does not have access to the raw scientific publications but has to rely on interpretations in the more popular articles which inevitably show some bias, the extreme greens will present a picture of approaching Armageddon.

Now if Joe is an older person like me, he has lived through the trial of the second world war when death could come at any time from a bomber in the sky, (which including China and Russia killed over 40 million people - double the population of Australia); - then the fear of atomic war which reached its climax with the Cuban blockade; - now the fear of terrorist attack which can occur anywhere at any time and with the mass use of drugs the possibility of some mutant drug resistant strain developing with a global pandemic - not a happy thought as the Spanish flue which followed the first world war and killed more people than all war time causalities in that worst of all wars.

And of course there is the chaos in the banking system leading to the global financial crisis with unemployment in the millions.

Not a happy place our earth. Joe's obvious question is how does climate change rank against these other threats.

At the other extreme is the barrage coming from the deniers who completely dismiss the reality of climate change or more realistically say the worse that will happen is that winter nights will be a bit warmer. Not a threatening idea for those old enough to have to get out of bed to use the toilet at night.

So how does Joe think through these divergent views? I have tried to promote the idea that Joe can ask if that view is readily tested by science, like the radiation meter I talked about earlier. Using this test he can be pretty sure that the basic information coming from science is reliable, measurements are for real.

The danger comes when scientist try to generalise these specific findings into general laws (climbing up the specialisation funnel) without testing the effect on the system. Data, based on experimental results is generally sound; failures tend to creep in when this data is examined for patterns leading to a general law. It is only when this law is tested under a variety of conditions that it can be treated as verified.

The Queensland floods were a classic test case for how to arrive at a reasonable view. The climate deniers were quick to argue that these floods were not exceptional and the floods of 1937 were a lot worse. The large damage was simply caused by their being more houses to damage and the increased paved area which increased the speed of run off. So they argue that this is not an indication of increased intensity of the flood and drought cycle.

Now I had firsthand experience of that flood with water running under my house so I naturally I took an interest. Peak rainfall data is available but data does not always tell the true story. As I say I lived through this and the striking reality is that peak rainfall was not the real issue. We had experienced a series of heavy rainfalls leading up to the peak rain, so when it came the ground was thoroughly saturated so the peak rain was devastating.

You had to live through the flood to know what questions to ask.

To get a valid comparison of both floods we would need to talk to someone who had lived through both floods, if there was a person who was mature age in the first flood they would now be 95 years old and probably suffering from memory loss (or exaggeration).

To form a view we really have to look at James Hansen's model of the loaded dice.

Joe Public does not need to go through all the statistics of extreme weather, all he need to do is satisfy himself that this is easily verifiable data, the work has been done for him, and this shows a significant increase in extreme weather.

Climate change is not about absolutes, it is about risks. Scientist are not very comfortable with risks, they prefer certainty, but ordinary people live with risk every day and take decision about risk all the time, often without thinking.

If the risk of an air crash was 1 in 1 (certain to crash) then any sensible person would say NO WAY

1 in 10 would not change that but when the risk is 1 in 100,000,000 then most people do what they do now - get on the plane and go.

When Joe tries to evaluate the dangers from extreme weather he is looking at a probability of 90% upwards, not totally guaranteed but pretty likely, similar to going to the milk bar and not being attacked by a lion that has just escaped from a travelling circus.

Joe has to way up the costs of avoiding climate change induced extreme weather against the downside. We know that the costs of extreme weather events are in the trillions of dollars but what is the alternative? What he is offered by the current climate change programs mean giving up fossil fuels, giving up the benefits of leaping from zero to a hundred kph in a semi military vehicle and living an Ashram life style, living in a cave, wearing a goat skins and eating cockroaches.

Joe Public has basically said thanks but no thanks, I'll live with the risk of floods and droughts, I will see them on the TV but they won't happen to me.

But my argument is that this is not the only option. We have the option of putting the carbon into the soil which gives us a breathing space of at least fifty years by which time some bright spark will have come up with a way of storing large amounts of power or some other solution which we have not even thought of.

Testing the idea

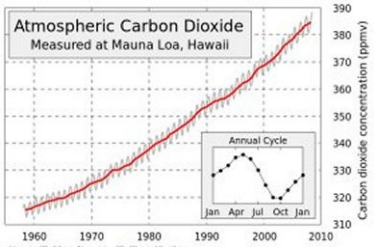
I have been pushing Joe Public to be critical of the information he receives and subject it to the test - can this be readily verified by a simple analysis.

The two planks in this argument are that 1) the soil can absorb sufficient amounts of carbon and that 2) plants are already taking much more carbon out of the atmosphere than we are putting in, and the only problem is to work out a way of stopping (or more realistically reducing) the amount of carbon dioxide being returned.

How can we do a quick test of how much carbon the soil can actually store, simple - look at the amount of carbon which is (or more correctly has) been stored in the savannah belts around the world which then look at the area of agricultural land that can be used as a carbon sink. No issue the soil can hold enough carbon to give us a breathing space.

The Keeling curves

But how much carbon are plants taking out of the atmosphere? Figures regularly crop up through the literature all giving massive figures but I have as yet to see the original calculations on which these are based. Perhaps all the authors assume this is common knowledge, in which case they are a bit out of touch with Joe.



But there is one set of figures which demonstrate this without question and that is the Keeling curves.

Again the Keeling curves are simply data using established techniques for measuring atmospheric carbon dioxide. Most people look at the trend showing ever increasing concentrations over the years. But the changes over a year are particularly interesting. Starting in the Northern spring in April they drop right down until autumn in October when generally the leaves fall of the trees.

What this clearly shows is that in the Northern summer the vegetation is taking carbon out of the air at a far faster rate than we are adding carbon. This is even more spectacular when we think that the Southern hemisphere is out of phase with the North so the net drop is because the land area of the North is so much larger than the South.

These graphs are the difference between the amount of carbon captures and the amount release back to the atmosphere by degradation and decomposition which again is highest in summer.

The just isn't any doubt about it - trees really work.

Slowing the carbon return

The debate cannot really continue without discussing why carbon so readily escapes from the soil. Without getting bogged down in technicalities it is all related to what thermodynamics would call entropy or relative stability, like a hill with the most unstable at the top and stable at the bottom. Carbon dioxide is at the bottom of the hill with the less stable compounds tending to convert into carbon dioxide at a rate that depends on their relative stability.

Carbon in plants does not exist as raw carbon but as complex organic molecules. The more complex they are the more easily they break down to form carbon dioxide. The soft tissues and leaves are highly unstable and are easily broken down by sunlight, bacteria and fungi as well as being eaten by many creatures, like cows and sheep, which convert them into carbon dioxide or methane.

Lignin or the hard substance in wood is relatively stable but is broken down by fungi, cut up by termites (for decomposition by captive fungi) or simply burned. Decomposition involves some release of carbon dioxide but may lead to the formation of humus.

Humus is highly stable, lasting for hundreds of years on the soil and is the key to soil carbon sequestration.

Much of the organic material from plants simply ends up as carbon dioxide without forming humus, however by carefully managing the process of decomposition higher proportion of the carbon can be formed into the stable humus.

The key is discovering that process and that is where limits of the scientific process become apparent.

System for soil carbon

Let me describe the current state of the art I have developed for regenerating soils. The essence is to manage the soil biology. These are the key features.

Continuous plant cover - soil biology relies on plants for energy. There must be a continuous supply of energy from plants or the critical fungi will die. This can be achieved by intercropping e.g. by planting the next crops between the existing row rows before harvesting the current crop or using permanent plants in alleys or islands. Using the land for a period under permanent pasture is another method.

Mycorrhizal fungi - plants take carbon directly from atmosphere, convert to sugars and carbohydrates which are taken up by the fungi which exude complex polymers into the soil which forms humus. Unfortunately mycorrhizal fungi are slow growing and delicate and require consistently humid soil. They are easily killed although the spores are very tough - this is their survival mechanism.

Deep burrowing worms - worms fulfill a number of functions in soil regeneration. Plants drop a large amount of organic material on the surface however if left on the surface much of this will simply oxidize without benefiting the soil structure. To be useful the organic material must be well below the surface. The right breed of worms, the deep burrowing varieties, will drag this surface organics deep into the soil.

Worms also seem to play an important role in helping mycorrhizal fungi to spread. It is not known whether this is caused by spreading the spores, aerating the soil or providing nutrients for the soil.

Bacteria - bacteria provide food for the worms that cannot directly digest plant material. They may eventually release nutrients to the soil but initially absorb nitrogen and do not contribute greatly to soil structure. Bacteria are however extremely tough and can survive over a wide range of conditions, wet or dry, and breed very rapidly.

Moisture - continuous moisture is critical in soil regeneration. Fungi and bacteria are in continuous competition for food; fungi are the most beneficial for soil regeneration but are easily damaged and need a consistently moist environment.

Fungi, which are critical for soil regeneration, are slow growing and only flourish over a narrow range of moisture.

Bacteria by contrast breed very rapidly and are much more robust and will flourish under a very wide range of moisture. Both fungi and bacteria are in competition for the same food supply. A key element in soil regeneration is to create the conditions where the fungi can out compete the bacteria. This means maintaining a steady moisture level over time.

The wicking bed technology is a system in which a reservoir of water maintains the soil moist by wicking action so the soil is kept moist, not saturated.

It is often used in conjunction with rows of 'soil trees' typically deep rooted legumes which add nitrogen and mine phosphorous. These also provide a home for mycorrhizal fungi

The Senna Alatus shown is an excellent 'soil' tree with large fast growing fleshy leaves which provide significant volumes of soil carbon.

Soil chemistry - soil biology, particularly the critical fungi, needs to be fed and have the right conditions. Nitrogen and calcium are crucial for fungi as is the soil Ph.

Capturing carbon in the soil

The critical question is - can we change agricultural procedures as a whole to capture more carbon in the soil. The answer to that question is yes, but we should adopt the systems approach to refine the changes needed to the agricultural procedures.

Widespread adoption of soil carbon farming thorough the world may be the one opportunity we have to avoid the hazards of climate change.

The fact is that using a fully integrated soil regeneration system it is possible to sequester large amounts of carbon into the soil. This is easiest and may be the only option to combat climate change in the short term. It gives us a breathing space while alternatives to fossil fuels are developed.

The punch line

Resolving climate change cannot wait for reductionist science to produce the answers. We need to adopt the process of the innovator, understanding the problem working out what technology is needed to resolve the problem then first searching all existing science to see if a solution already exists, if not developing the needed technology then integrating this into the solution.

The problem is clear. Resolving climate change requires a dramatic reduction in fossil fuel use. The economic needs of developing countries and the wish to maintain a comfortable life style in the affluent countries means that simply stopping using coal and oil is not an acceptable option in the short term.

There is an abundant supply of sustainable energy in wind, solar and wave power but these have the immediately practical problem that they cannot be controlled, the energy cannot be stored and released when needed. Given time the technology could be developed but that could take up to fifty years. Until this technology is developed cutting back on greenhouse gases by abandoning fossil fuels simply will not happen.

Embedding carbon in the soil provides an effective way of giving us a breathing space for this technology to emerge. The reductionist approach of science, examining every aspect of embedding carbon in the soil is not going to give us the perfected technology in the short term. But the techniques of capturing carbon in the soil have already been solved by the innovators approach of developing a system. Even if every minute detail is not understood, the system can be refined over time.

Embedding carbon in the soil means that agricultural practices need changing. Raising the organic content of soil also has benefits in food security and quality. Changing agricultural practices is easily achieved by developing suitable financial incentives for the farmer. There are many ways of achieving this, carbon trading is currently the most fashionable but the mechanics of carbon trading schemes have to be simple and accessible for the farmer.

It may be helpful for our policy makers to consider the similarity between the development of the steam engine and resolving climate change.

The steam engine was developed to solve an immediate and practical problem, the flooding of mines. We have an immediate and practical problem with food production and managing the impact of the increased flood and drought cycle from climate change.

The early steam engines did their job of pumping out the mines, the mine owners did not wait for the science to catch up they acted. Later steam engines were refined by the scientific understanding of thermodynamics developed by Carnot.

Right now we have the technology of how to embed carbon in the soil - it works and can offset carbon emissions. Scientific understandings of the complexities of soil microbiology will no doubt improve with time but we should not wait - we need to act now.