

The Great Restoration

CLEANING UP CARBON



TIM KRUGER IS A LEADING AUTHORITY ON REMOVING CARBON DIOXIDE FROM THE ATMOSPHERE.

He shares his time between the University of Oxford and a cleantech startup, Origen. Tim runs a programme at the Oxford Martin School which assesses the range of proposed techniques for removing greenhouse gases from the atmosphere to determine which, if any of them, could be deployed at meaningful scale without creating countervailing side-effects. Origen is developing a technology, based on the lime cycle, to remove carbon dioxide from the air. You can find out more at origencarbonsolutions.com



TIM KRUGER

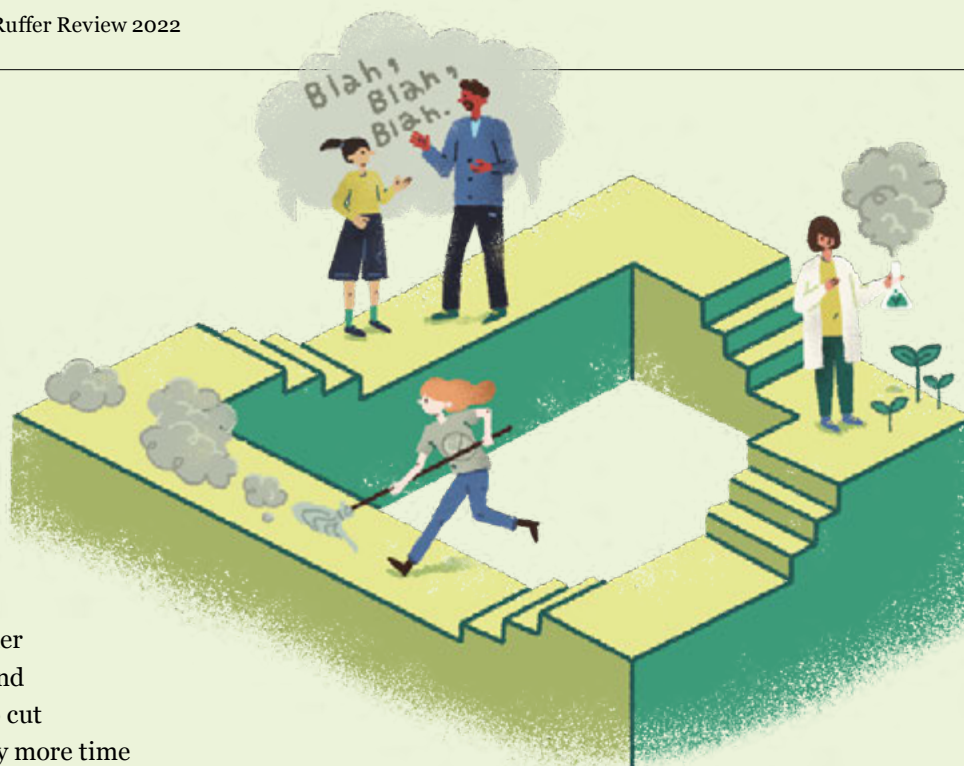
*Founder at Origen and
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ONCE UPON A TIME THE CLIMATE WAS STABLE.

For the past 8,000 years we have benefited from a period of climate calm. That stability enabled the development of agriculture, settled living and civilisation. It was foundational to the modern world.

Those foundations are now being shaken. Throughout those eight millennia temperatures might have jiggled about slightly, but they were always within a tight band deviating, at most, by about half a degree from the average. We are now busting out of that range – temperatures are up by a whole degree in the past century and there's every expectation that they will rise much further.

Some people are unperturbed by global warming – what difference does a degree



or two make? A warmer world might even sound like an opportunity to cut heating bills and enjoy more time on the beach each summer. However, we need to think of our planet's temperature as we would our own. A degree rise on the thermometer is discomfort, two degrees is a raging fever, three is potentially fatal.

We need to calm the fever. The good news is we know how to. The bad news is we may choose not to. Curing climate change is not beyond the wit of man, but it may be beyond our will.

REDUCE AND REMOVE

Decades of climate negotiations have served us equal helpings of hope and cynicism. For glass-half-fullers, the very fact that the divergent interests of the planet's nations have been aligned in climate-calming ambition is little short of a miracle, while glass-half-emptiers can point to the stark gap between saccharine statements of intent and the dearth of action.

For all the criticism that recent climate talks were, in the words of Greta Thunberg, "blah, blah, blah", there were two substantive outcomes. Firstly, the global commitment to 'phase down' coal heralds the end of the

fossil energy era – and not just for coal – oil and gas too are going the way of the dinosaurs. And secondly, Net Zero is going to happen – over 90% of the global economy is now committed to that goal.¹

Those two outcomes talk to both halves of the walnut of what it will take to cure climate change. Reduce and remove. The first priority is to reduce – cutting emissions – but we will also need to remove colossal quantities of carbon dioxide from the air in the decades ahead.

This points to two inevitable megatrends. One relates to the transition from our existing, fossil energy-based society to one powered by renewables. The other relates to Greenhouse Gas Removal, the nascent field of proposed techniques for removing carbon dioxide from the air and squirrelling it away permanently, deep underground.

The rise in global temperatures depends on cumulative emissions. Stopping the rise in temperatures will require not just a decrease in emissions, but a complete halt.

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To prevent temperatures continuing to rise it will be necessary to achieve Net Zero – reducing emissions and then counteracting any remaining emissions with equivalent removals.

If we manage to cut emissions along the lines projected in the climate models (a massive ‘if’ – it would require an outbreak of competence and commitment hitherto unwitnessed in the history of humanity) we would still need to remove about a trillion tonnes of carbon dioxide from the atmosphere over the next 80 years. Think of it as a new waste management industry, on a stupendously large scale.

Can we achieve removals at the scale and pace required? I believe we can. This is not the place to delve into the range of possible approaches and their various benefits and side-effects.² Suffice to say there is unlikely to be a single technique that will do it on its own – no silver bullet, but perhaps a portfolio of techniques which together could form the silver buckshot required to stop climate change in its tracks.

THE EARTHSHOT CHALLENGE

In late 2021, to galvanise the development of removal technologies, the United States Department of Energy announced a new Earthshot challenge which seeks to emulate

Kennedy’s famous Moonshot in ambition and scope. They have set a target to reduce the cost of removing carbon dioxide from the atmosphere to \$100 per tonne by 2030.³ Many think this is a pipedream.

Having worked in this field long before it was fashionable as both an academic and as an entrepreneur, I believe this is eminently achievable.⁴ What hasn’t been considered nearly deeply enough are the consequences of actually achieving this goal.

What would be the implications if we could safely, robustly and scalably remove carbon dioxide from the atmosphere at \$100 per tonne?⁵ Achieving the Earthshot challenge would have profound consequences – and some surprising ones too.

I believe having the ability to remove carbon dioxide from the air at scale would establish a carbon price that is rational, moral and global. It would also open the possibility of going beyond Net Zero. And it has the potential to transform petro-economies into climate champions.

A RATIONAL PRICE FOR CARBON

While economists have long called for a global carbon price to address climate change, the means by which to implement this mechanism have been elusive.

But if we developed techniques that could remove CO₂ from the air at say, \$100 per tonne, then this is what the price of carbon would become.

Carbon dioxide is a pollutant: it results in damage to society by causing climate change. Currently, the principle of ‘the polluter pays’ is not enforced; the costs of pollution are not being borne by the polluter and the ‘permits to pollute’ are less than the cost of the damage caused. This is a de facto subsidy of carbon dioxide producers.

2 CDR Primer

3 Office of Fossil Energy and Carbon Management

4 Origen Carbon Solutions

5 In this instance: ‘safe’: socially and politically acceptable; ‘robust’: results in long-term storage of CO₂ away from the atmosphere; ‘scalable’: can be deployed at a scale to counteract all of humanity’s emissions

The pricing of carbon dioxide is often referred to as a carbon tax. But it isn't a tax – rather, it's a reduction to a subsidy. With carbon dioxide producers not paying the cost of the pollution they are causing, they are in effect being subsidised by society – a transfer of wealth from society to polluters.

A MORAL PRICE FOR CARBON

The emergence of techniques that can remove CO₂ from the air will determine the correct carbon price and create a moral obligation to use such techniques. The sin is not emitting carbon dioxide into the atmosphere – the sin is failing to clean it up. In the absence of the means to clean up the mess, a polluter can justify their inaction by saying “I can't clean it up”. Once such techniques exist, they can only say “I don't want to clean it up” – a very different moral position.

While regulatory change may be slow – legislators will be lobbied ferociously by those industries that would buckle under the pressure of having to internalise the externalities they inflict upon society – judicial action may bring about changes far

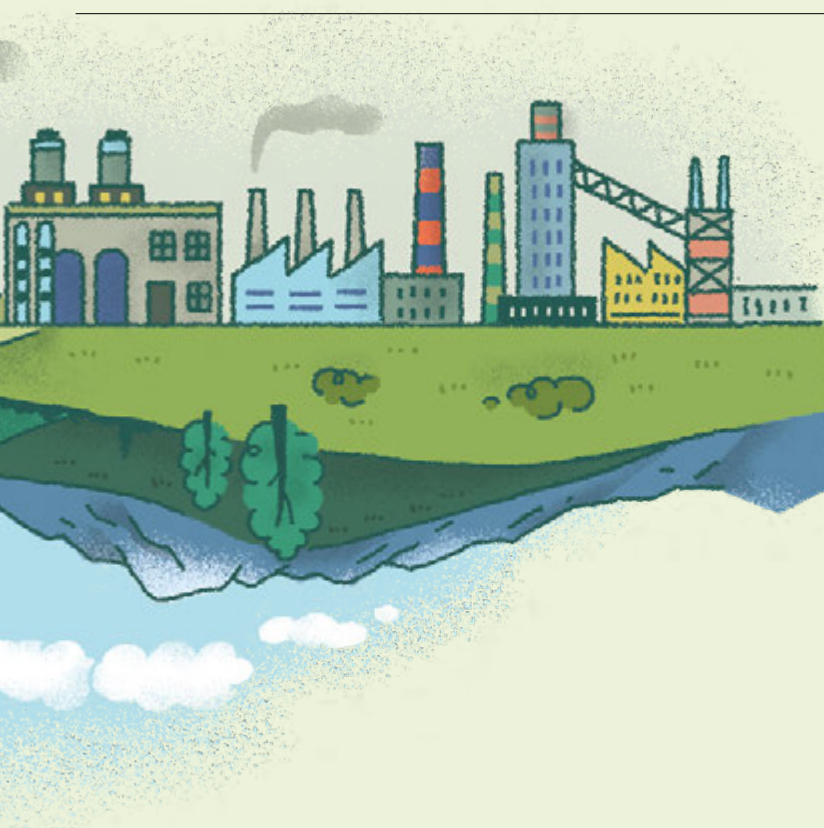


quicker. Jurists applying remedial actions for the tort of climate change may require emitters to match each tonne of emissions with an equivalent amount of removal. If such action costs \$100 per tonne and you, as an emitter, are not willing or able to bear such a cost then you would have to cease operating.

This may seem harsh, but only if we benchmark against current carbon pricing mechanisms that neither reflect the amount of harm done by emissions, nor recompense those harmed.

A GLOBAL PRICE FOR CARBON

Scalable techniques to remove carbon dioxide from the air could create a global carbon price. Doing so would overcome the issue of ‘carbon leakage’ – the moving of high-emitting industries to jurisdictions where the costs of the sins of emissions are less onerous. It is important to note,



6 World Bank. On average, wealthier countries tend to produce more economic output per unit of carbon dioxide emissions than less wealthy countries. For example, if countries were required to pay \$100 per tonne of CO₂ emitted, it would cost the US about 2% of its GDP, while it would cost China 5% of its GDP (which is far smaller on a per capita basis)

7 Oxford Martin School, University of Oxford

8 Lackner (2013), The thermodynamics of direct air capture

however, that a universally applied carbon price would hit poorer countries harder than richer ones and so would likely be regressive in nature.⁶

A uniformly applied carbon price on emissions would take no account of historic emissions from countries that industrialised earlier. The fact that carbon dioxide persists in the atmosphere for so long means that the whole world is suffering the consequences of emissions from centuries ago. The fact that those emitters did not know that their actions would result in long-term harm does not absolve responsibility for that harm.

HISTORIC NET ZERO

Countries who started down the path to industrialisation later feel like latecomers to a five-course dinner. They arrive in time for dessert and then the other people in the group expect them to split the overall bill equally. A mechanism that acknowledges

both current and historic emissions will be essential to achieve global agreement.⁷

Ultimately, achieving Net Zero will require that each emission is matched with a removal and for the carbon price to rise to the cost of removing CO₂ from the air. But we need to strive not only for Net Zero on an ongoing basis, but also aim to achieve Historic Net Zero, scrubbing as much carbon dioxide out of the air as has been emitted since the Industrial Revolution. While we may protest at the costs that would fall on us due to the actions of our ancestors, it seems fair that those economies that benefited from earlier industrialisation should have to pay the appropriate share of the clean-up bill. Industrialised countries have inflicted a carbon hangover on the whole of humanity – it's time to pick up the tab.

TRANSFORMING PETRO-ECONOMIES INTO CLIMATE CHAMPIONS

For economies that rely on fossil energy this would all seem like pretty bad news, but it needn't be so. There may be a way in which those countries that are the repositories of the hydrocarbons which have the potential to wreck the climate could in fact become climate champions. They can use the energy buried beneath their land to become leaders in what will become a major new economic activity – the removal of carbon dioxide from the air. In fact, they could make more money being part of the solution to climate change than they currently earn causing it.

And this is where the countries rich in fossil energy can play a key role. To remove carbon dioxide from the air requires energy (that's a thermodynamic fact – not the kind of fact you want to argue with).⁸ Countries with access to fossil energy also

have a few other things in their favour: the correct geology (the formations that held hydrocarbons secure for millions of years can also be used to permanently store carbon dioxide captured from the air), expertise in large-scale engineering and access to capital.

Currently, burning natural gas results in emissions of carbon dioxide into the atmosphere, contributing to climate change. For every MMBTU of natural gas burnt about 50kg of carbon dioxide goes into the air.⁹ It is possible to use that same MMBTU of natural gas to power a process that will result in 150kg of carbon dioxide being removed from the air.¹⁰ In a world where the carbon price is \$100 per tonne you would see an additional \$5 per MMBTU going onto the price of the natural gas being burnt. Alternatively, the owner of that natural gas could earn revenue of \$15 per MMBTU – and be applauded for countering climate change.

No doubt many environmentalists would be horrified at the idea that those countries who profited from actions which caused

“ Our ambition must not be to change the world, but rather to keep it as it’s meant to be – to go forward, we need to go back.”

climate change could profit further from clearing up the mess that they made. But others would argue that if this is the price to pay for avoiding a greater harm, then that’s what is required. Using fossil energy to counter climate change, whilst seemingly a paradox, could allow us to restore the atmosphere.

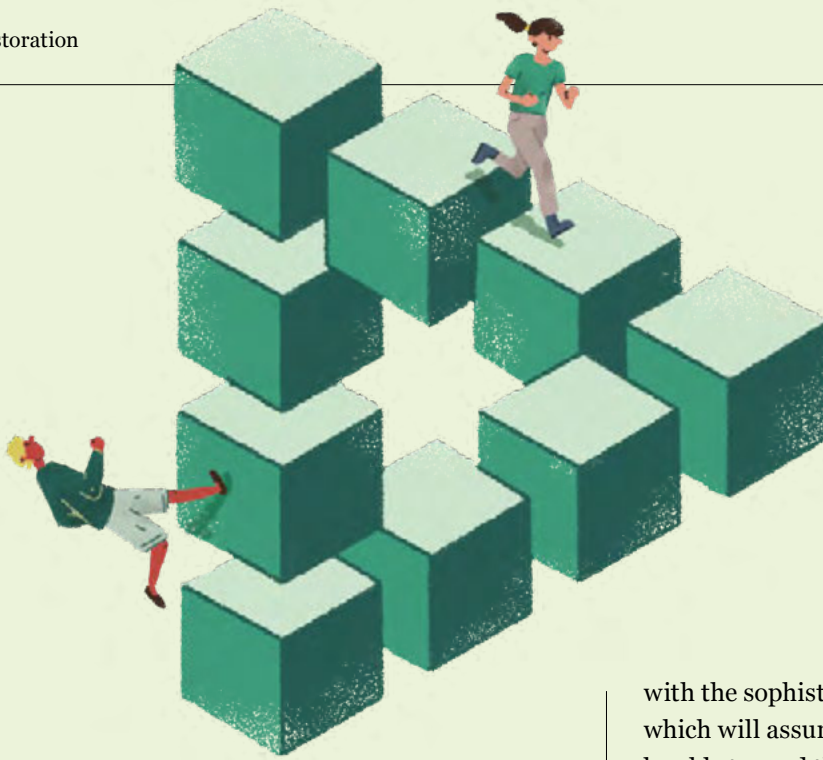
It could also break the logjam on climate negotiations. Climate change is an existential threat to all humanity, but action to counter climate change is itself an existential threat to the economies of countries that sell fossil energy. We need to imagine a world in which the owners of fossil energy are actually motivated to call for faster action to counter climate change.

The discomfort we feel at the messy compromises that we will need to make to clean up the mess of climate change is real and important. We all have our agendas: coal miners whose livelihoods depend on being deaf to climate science; those on the left who see the climate crisis as the anvil upon which to break capitalism (and who view any action which doesn’t advance that goal as unacceptable); and the vast swathes of the uninterested who really can’t



⁹ MMBTU: a million British Thermal Units, the unit most used in the gas industry, or 1.055GJ or about 0.172 barrels of oil equivalent

¹⁰ Full disclosure – the process I have in mind here, is the one that my company is developing



understand what all the fuss is about and demand that their lives are as undisrupted and untaxed as possible.

Climate change is what is known as a ‘wicked problem’ – ‘wicked’ in the sense that it is resistant to resolution, rather than evil.¹¹ The range of agendas and worldviews that characterise humanity suggest that there is unlikely to be a single solution which everyone will support. Demonstrating that we can remove carbon dioxide from the air in ways that are scalable and cheap will not miraculously lead to global harmony, but it could take the heat out of the arguments – and indeed out of the climate itself.

THE GREAT RESTORATION

The millennia of stable climate since the last Ice Age is known to geologists as the Holocene. As geological eras go, it is a short one, but it is already drawing to a close. It is being superseded by a new age – the Anthropocene – where the influence of one species of ape is leaving an indelible mark on the planet. A billion years hence a species

with the sophistication of our own (but which will assuredly not be our own) will be able to read the runes of the emergence of industrial *homo sapiens* etched in the rocks. This display of geological graffiti is not something of which to be proud.

We need to harness the ingenuity that has got us this far to undo the harm, to scrub the stain of the Anthropocene. Our ambition must not be to change the world, but rather to keep it as it’s meant to be – to go forward, we need to go back. Such is the damage that we have inflicted it will require a multi-generational endeavour to de-disturb our planet’s systems.

This ‘Great Restoration’ will require us to return the composition of the atmosphere back to one compatible with a stable climate and healthy oceans. We need to remember a lesson we learnt in kindergarten – if you make a mess, you have to clean it up. But restoring the planet will cost money – a few percent of global GDP on an ongoing basis – and we seem reluctant to pay.

Humanity has the capacity to cure climate change – the question is not so much “can we?” as “will we?” Our actions now will determine whether or not future generations are able to live happily ever after. ●

11. Rittel, Webber (1973), Dilemmas in a general theory of planning