Australian Government

Chief Scientist

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THE ORDERLY TRANSITION TO THE ELECTRIC PLANET

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When I was growing up, one of the formative images that seared itself on my brain was a picture taken by the astronauts of Apollo 11.

It was a picture of Earth, one of the first full-colour perspectives of our planet. A wondrous ball of bright blue, lightly veiled with swirling white clouds, peeking out of the eternal darkness of space.

Of course, that photograph highlighted another aspect of our existence: our fragility. Growing up in the 1960s we lived with the possibility that our beautiful planet would be wiped out in unconstrained nuclear war.

The United States and Soviet Union had armed themselves with enough nuclear weapons to obliterate the human race several times over, with both sides publicly committing to immediate retaliation in the event of a first strike.

The only outcome of such a defence would be mutually assured destruction. With the stunningly appropriate acronym, MAD.

For years, the terrifying prospect was that the image in that photograph, that blue marble containing all we know and cherish, could vanish in a single flash of light. A single moment of MAD-ness.

Such was the fear, that a young American wrote to President Kennedy "I am eleven years old and every night I worry. What will be left of this wonderful world if someone presses the button? What will be left of you and your family?"[i]

Late last year, I received my own letter from a child.

My 10-year-old grandniece, Elise, wrote to me: "Uncle Alan, I just watched a frighteningly real video on the crisis of sustainability. I would love it if you could talk to my school about what we can do, how we can help, and what is actually going on".

Now, there is a world of difference between nuclear war and climate change, but we cannot deny that for the next generation, climate change is one of their biggest concerns when contemplating the future.

Elise, I'd like to reassure you that just as mutually assured destruction was supplanted with mutual international cooperation, so too can we take collective action on climate change.

And so, Elise, as Australia's Chief Scientist, I take this opportunity to outline the science of climate change, and how we can use science and technology to address it.

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Around the time we started exploring space, scientists began to monitor and study the Earth's atmosphere.

In the 1970s, the CSIRO and the Bureau of Meteorology created a joint research station at Cape Grim, in Tasmania, and began sampling the most pristine air in the world.

And what they have recorded is an unrelenting increase in the levels of carbon dioxide in our atmosphere.

At the start of the Industrial Revolution, it was 280 parts per million. Today the concentration is 409 parts per million,[ii] a level not experienced for four million years[iii] — a time pre-dating humans, when giant sloths and mastodons roamed the Earth.[iv]

And there is absolutely no hint of a slowdown. Annual carbon dioxide emissions from human activities increased from 24 billion tonnes in 1998 to 37 billion tonnes in 2018, and the atmospheric concentration rise last year was one of the highest annual increases ever.

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Our understanding of how these emissions impact our planet dates back almost 200 years, to 1824, when an extraordinary French mathematician, Joseph Fourier, whose work continues to shape engineering today, asked a simple question, as scientists often do: what is regulating Earth's temperature?

Fourier's answer was that the atmosphere was keeping the Earth's surface warm, like the glass windows in a greenhouse, hence the term 'the greenhouse effect'.

Although the process is more complicated than that, Fourier provided a straightforward analogy that is still widely used.

In 1896, a Swedish chemist named Svante Arrhenius went a step further and determined the underlying physics of how global warming actually works.

As the sun shines through our atmosphere, the Earth's surface warms and emits some of the sun's energy as infrared radiation.

Ordinarily, this infrared radiation would escape to space. However, Arrhenius found that some gases, like carbon dioxide, trap this infrared radiation and then re-emit it in all directions.

While some of that re-emitted infrared radiation makes its way back into space, the rest heats the Earth's atmosphere, surface and oceans, making them warmer than they would otherwise be.

We depend on these greenhouse gases to support all life on Earth. Without them, the Earth would lose so much heat that life as we know it would be impossible.

The problem we are addressing occurs when greenhouse gas levels get too high because of human activities, trapping too much of the sun's energy as heat. This is referred to as the *enhanced* greenhouse effect.

And the last decade was hot. Really hot.

In fact, my 10-year-old grandniece Elise has already lived through seven of the hottest years in recorded Australian history.[v]

It is important to recognise that global warming is just that; *global*. No nation is immune to its impact. Indeed, many nations that contribute the least to global warming are facing its most serious consequences.

Because ocean currents and major wind patterns respond to atmospheric and ocean warming, the effect of just one degree temperature rise causes major disruptions on the natural systems that regulate our climate.

Small annual temperature changes eventually lead to tipping points, resulting in increasingly intense storms, deeper droughts, erratic swings in coastal water temperatures and consequent coral bleaching.

These extreme weather events will not only persist but will be more severe, and in some cases more frequent, into the future.

Climate change is Nature's reaction to our actions.

It is real, and it is already happening with a rapidity that is deeply affecting our way of life.

The link between climate change, a rising number of forest fire danger days and our season of bushfires is clear, and has resulted in a steep collective cost that can be measured in billions of dollars in economic

damage — which pales to insignificance when compared to the greater costs behind the statistics.

The lost lives and livelihoods. The lost businesses and homes. The lost flora and fauna.

These costs are immeasurable, and I express my condolences here today to everyone affected by the devastating bushfire emergency this summer, especially all those who have lost loved ones.

Unless long-term action is taken, these extreme bushfires conditions will be repeated, and indeed continue to worsen, into the future.

We cannot wish it away. So, what can we do?

First, as the Prime Minister noted two weeks ago in this very room, “Practical action on mitigation through reduced emissions needs to go hand-in-hand with practical action on climate resilience and adaptation”.

Among many initiatives announced by the Commonwealth and State Governments, including billions of dollars in support for bushfire relief, I have been asked by the Prime Minister to chair an expert advisory panel that will support the CSIRO in the development of advice to all governments on climate and disaster resilience.

Second, as Minister Karen Andrews has declared, as a nation we must move on from disputing the reality of climate change.[vi]

As a global community, as agreed in Paris in 2015, and as we will see discussed in Glasgow later this year, we must work together on the next phase of emissions reduction.

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A practical mitigation approach is to address the biggest source of emissions.

Nearly three quarters of global emissions come from energy used for transport, heating and industry, as well as traditional electricity generation.[vii] So, focussing on energy will present us the best return on investment.[viii]

But we cannot abruptly cease our use of energy.

An energy supply is the most essential pillar of our civilisation.

Without an energy supply, it's back to the Stone Age.

Just think about the last 300 years since the invention of the steam engine – everyone in this room is a beneficiary of energy-driven conveniences that make our daily lives easier and more productive.

Given this, the only way to meet the energy needs of the future without sacrificing standards of living, or undermining the economy, is by planning for an orderly transition that embraces science and technology as the stepping stones to the future we want.

A future where we supply the vast majority of our energy requirements by electricity. Clean electricity. Not just for lighting, computing and air conditioning, but for transport, building heating, and industry, too.

A future I like to call the "Electric Planet".

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I want you to imagine a highway exclusively devoted to delivering the world's energy.

Each lane is restricted to trucks that carry one of the world's seven large-scale sources of primary energy: coal, oil, natural gas, nuclear, hydro, solar and wind.

Our current energy security comes at a price, the carbon dioxide emissions from the trucks in the three busiest lanes: the ones for coal, oil and natural gas.

We can't just put up roadblocks overnight to stop these trucks; they are carrying the overwhelming majority of the world's energy supply.

But, what if we expand clean electricity production carried by the trucks in the solar and wind lanes — three or four times over — into an economically efficient clean energy future

Think electric cars instead of petrol cars. Think electric factories instead of oil-burning factories.

Cleaner and cheaper to run.

A technology-driven orderly transition.

Problems wrought by technology, solved by technology.

Make no mistake, this will be the biggest engineering challenge ever undertaken. The energy system is huge, and even *with* an internationally committed and focussed effort the transition will take many decades.

It will also require respectful planning and re-training to ensure affected individuals and communities, who have fuelled our energy progress for generations, are supported throughout the transition.

As Tony, a worker from a Gippsland coal-fired power station, noted from the audience on this week's Q&A program: "The workforce is highly innovative, we are up for the challenge, we will adapt to whatever is put in front of us and we have proven that in the past."

This is a reminder that if governments, industry, communities and individuals share a vision, a positive transition can be achieved.

The stunning technology advances I have witnessed in the past ten years make me optimistic.

Renewable energy is booming worldwide, and is now being delivered at a markedly lower cost than ever before.

In Australia, the cost of producing electricity from wind and solar is now around AUD$50 per megawatt-hour.[ix]

Even when the variability is firmed with storage, the price of solar and wind electricity is lower than existing gas-fired electricity generation and similar to new-build coal-fired electricity generation.[x]

This has resulted in substantial solar and wind electricity uptake in Australia,[xi] and, most importantly, projections of a 33% cut in emissions in the electricity sector by 2030, when compared to 2005 levels.[xii]

And this pricing trend will only continue, with a recent United Nations report noting that, in the last decade alone, the cost of solar electricity fell by 80%, and is set to drop even further.[xiii]

So we're on our way. We *can* do this. Time and again we have demonstrated that no challenge to humanity is beyond humanity.

But we cannot be naïve about the scale of the task ahead nor can we afford to discard any of the tools at our disposal.

I have always maintained that the focus needs to be on outcomes. The outcome in this case is reduced atmospheric emissions. We should use whatever underlying technologies achieve the goal.

Different nations will have different energy mixes and needs, but what does the generation technology matter if the outcome – atmospheric emissions – is lowered?

Nevertheless, in Australia, with nuclear energy and *new* hydroelectricity facing significant public opposition, we are theoretically limited to fitting all our future energy traffic into just two lanes: solar and wind.

But, there is a limit to how much solar and wind we can use and still retain a reliable system.

Ultimately, we will need to complement solar and wind with a range of technologies such as high levels of storage, long-distance transmission, and much better efficiency in the way we use energy.

But, while these technologies are being scaled up, we need an energy companion today that can react rapidly to changes in solar and wind output. An energy companion that is itself relatively low in emissions, and that only operates when needed.

In the short-term, as the Prime Minister and Minister Angus Taylor have previously stated, natural gas will play that critical role.

In fact, natural gas is already making it possible for nations to transition to a reliable, and relatively low emissions, electricity supply.

Look at Britain, where coal-fired electricity generation has plummeted from 75% in 1990 to just 2% in 2019.[xiv]

Driving this has been an increase in solar, wind, and hydro electricity, up from 2% to 27%.

At the same time, and this is key to the delivery of a reliable electricity supply, electricity from natural gas increased from virtually zero in 1990 to more than 38% in 2019.[xv]

Closer to home, look at South Australia's success in increasing solar and wind electricity to 51% in the last fiscal year. Again, natural gas is key to the stability of the electricity supply, accounting for 47%.[xvi]

I am aware that building new natural gas generators may be seen as problematic, and I will come back to that, but, for now, let's assume

that with solar, wind and natural gas, we will achieve a reliable, low emissions electricity supply.

Is this enough? Not really.

We still need a high-density source of transportable fuel for long distance, heavy duty trucks.

We still need an alternative chemical feedstock to make the ammonia used to produce fertilisers.

We still need a means to carry clean energy from one continent to another.

Enter the hero: hydrogen.

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Hydrogen is abundant. In fact, it's the most abundant element in the universe. The only problem is that there is nowhere on Earth that you can drill a well and find hydrogen gas.

Don't panic.

Fortunately, hydrogen is bound up in other substances. One we all know: water, the H in H-2-O.

We have two viable ways to extract hydrogen, with near-zero emissions.

First, we can split water in a process called electrolysis, using renewable electricity.

Second, we can use coal and natural gas to split the water, and capture and permanently bury the carbon dioxide emitted along the way.

I know some may be sceptical, because carbon capture and permanent storage has not been commercially viable in the electricity generation industry.

But, the process for hydrogen production is significantly more cost-effective for two crucial reasons.

First, since carbon dioxide is left behind as a residual part of the hydrogen production process, there is no additional step, and little added cost, for its extraction.

And second, because the process operates at much higher pressure, the extraction of the carbon dioxide is more energy efficient and it is easier to store.

Returning to the electrolysis production route, we must also recognise that if hydrogen is produced exclusively from solar and wind electricity, we will exacerbate the load on the renewable lanes of our energy highway.

In my training as an engineer, I was taught to build safety margins and redundancy into critical systems.

Now, you might say to me, “Alan, we’re never going to run out of sunshine and wind.”

But think for a moment of the vast amounts of steel, aluminium and concrete needed to support, build and service solar and wind structures.

And the copper and rare earth metals needed for the wires and motors.

And the lithium, nickel, cobalt, manganese and other battery materials needed to stabilise the system.

What if there was a resources shortage?

It would be prudent, therefore, to safeguard against any potential resource limitations with another energy source.

Well, by producing hydrogen from natural gas or coal, using carbon capture and permanent storage, we can add back *two* more lanes to our energy highway, ensuring we have four primary energy sources to meet the needs of the future – solar, wind, hydrogen from natural gas, and hydrogen from coal.

Furthermore, once extracted, hydrogen provides unique solutions to the remaining challenges we face in our future Electric Planet.

First, in the transport sector, Australia’s largest end user of energy.

Because hydrogen fuel carries much more energy than the equivalent weight of batteries, it provides a viable, longer range, alternative for powering long-haul buses, B-double trucks, trains that travel from mines in central Australia to coastal ports, and ships that carry passengers and goods around the world.[xvii]

Second, in industry, where hydrogen can help solve some of the largest emissions challenges.

Take steel manufacturing.

In today's world, the use of coal in steel manufacturing is responsible for a staggering 7% of carbon dioxide emissions.[xviii]

Persisting with this form of steel production will result in this percentage growing frustratingly higher as we make progress decarbonising other sectors of the economy.

Fortunately, clean hydrogen can not only provide the energy that is needed to heat the blast furnaces, it can also replace the carbon in coal used to reduce iron oxide to the pure iron from which steel is made. And with hydrogen as the reducing agent the only by-product is water vapour.

This would have a *revolutionary* impact on cutting global emissions.

Third, hydrogen can store energy, not only for a rainy day, but also to ship sunshine from our shores, where it is abundant, to countries where it is needed.

Let me illustrate this point. In December last year, I was privileged to witness the launch of the world's first liquefied hydrogen carrier ship in Japan.

As the vessel slipped into the water I saw it not only as the launch of the first ship of its type to ever be built, but as the launch of a new era in which clean energy will be routinely transported between the continents. Shipping sunshine.

And, finally, because hydrogen operates in a similar way to natural gas, our natural gas generators can be re-configured in the future to run on hydrogen — neatly turning a potential legacy into an added bonus.

We truly are at the dawn of a new, thriving industry.

There's a nearly A$2 trillion global market for hydrogen come 2050, assuming that we can drive the price of producing hydrogen to substantially lower than A$2 per kilogram.[xix]

In Australia, we've got the available land, the natural resources, the technology smarts, the global networks, and the industry expertise.

And we now have the commitment, with the ‘National Hydrogen Strategy’ unanimously adopted at a meeting by the Commonwealth, State, and Territory Governments late last year.

Indeed, as I reflect upon my term as Chief Scientist, in this my last year, chairing the development of this strategy has been one of my proudest achievements.

The full results will not be seen overnight, but it has sown the seeds, and if we continue to tend to them, they will grow into a whole new realm of practical applications and unimagined possibilities.

The national hydrogen strategy provides a framework for Australia to cost-effectively become a world-leader in this new industry.

We have the potential to be one of the top three exporters of clean hydrogen, to create an exemplary safety track record, thousands of new Australian jobs, especially in regional areas, and billions of dollars in economic growth between now and 2050.

And we’re on our way to meeting this goal.

State Governments right around the country have introduced funded hydrogen action plans, departmental teams have been established to ensure their effective roll-out, and the Commonwealth Government has announced $370 million of hydrogen stimulus funding, including $70 million for an ARENA funding round already in motion.

By building on this progress, Australia can simultaneously confront the environmental challenges threatening our nation and the world, while laying the groundwork for our long-term economic security and prosperity.

I have every confidence we can do it. For we are Australians. Born, in the words of Henry Lawson, “to be thinkers and doers, and makers of wonderful things”.[xx]

We are resilient and bold and possess, as Dame Enid Lyons once noted, “qualities of initiative and daring that…will never be allowed to die”.[xxi]

Our proven capacity for greatness, for courage to go beyond the seemingly impossible, is how we have led in the pursuit of new horizons; it’s how we have helped shape the world.

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I want to leave you today with one more letter, written by a man who left his small town to embark on a historic mission, which was helped, in part, by our nation's ingenuity.

"Down in Australia", the letter goes, "there were some very dedicated people…instrumental in the success of man's first flights to the moon.

"Science fiction writers thought it would be possible…to get people to the moon. But none…foresaw any possibility of the lunar explorers being able to…transmit moving pictures of what they saw back to Earth.

"I was probably the most surprised person in the human race when Mission Control announced they were getting a picture.

"So I will just say thanks, mates. Neil Armstrong".[xxii]

Thanks to Australia's radio telescope facilities in Parkes and Honeysuckle Creek, 600 million people around the world stood as one and watched the moon landing on their television screens – inspiring wonder and sparking passions in a new generation, including a young teenager in Melbourne who became enamoured with all things science and who stands before you here today.

The task of dealing with the challenge of climate change will require the same spirit of unity, enterprise and achievement.

It will require each of us to believe in ourselves and in our ability to accomplish great deeds.

To believe, that with imagination and technological innovation, and perseverance across decades, we will meet this challenge, and preserve the image in that photograph that seared itself on my brain all those years ago.

Long after the Apollo 11 mission, when astronaut Michael Collins was asked how it felt to take that photo, to see the Earth majestically rising above the lunar surface, he responded:

"Oddly enough the overriding sensation I got looking at the Earth was: my God, that little thing is so fragile out there".[xxiii]

Let us all reflect on this simple yet powerful message.

We only have one precious planet to call home, and we all hold a great responsibility in our tenancy here, to children like Elise, and to generations yet to come.

Thank you.

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[i] Rhodes, J.P. (2017). *Growing Up in a Land Called Honalee*: *The Sixties in the Lives of American Children*. Columbia: University of Missouri Press. p.81

[ii] https://www.csiro.au/en/Research/OandA/Areas/Assessing-our-climate/Latest-greenhouse-gas-data

[iii] "Atmospheric CO2 is already at levels last seen around four million years ago, in the Pliocene epoch." https://www.nature.com/articles/d41586-019-03595-0

[iv] https://www.britannica.com/science/Pliocene-Epoch

[v] http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=timeseries

[vi] https://www.abc.net.au/news/2020-01-15/cabinet-ministers-karen-andrews-climate-change-time-wasters/11868694

[vii] https://www.c2es.org/content/international-emissions/

[viii] https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

[ix] Graham, P., Hayward, J., Foster, J. and Havas, L. 2019, GenCost 2019-20: preliminary results for stakeholder review CSIRO, Australia.

[x] http://re100.eng.anu.edu.au/publications/assets/100renewables.pdf

[xi] In 2019, Australia installed a record 6.3 gigawatts of new renewable capacity, following an investment of $11.9 billion in renewable energy in 2018, our highest on record.

[xii] Commonwealth of Australia. *Australia's emissions projections 2019*.

[xiii] https://www.unenvironment.org/news-and-stories/press-release/decade-renewable-energy-investment-led-solar-tops-usd-25-trillion

[xiv] https://www.nationalgrid.com/britain-hits-historic-clean-energy-milestone-zero-carbon-electricity-outstrips-fossil-fuels-2019

[xv] https://www.nationalgrid.com/britain-hits-historic-clean-energy-milestone-zero-carbon-electricity-outstrips-fossil-fuels-2019

[xvi] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2019/2019-South-Australian-Electricity-Report.pdf

[xvii] Commonwealth of Australia. *Australia's National Hydrogen Strategy*

[xviii] https://www.worldsteel.org/publications/position-papers/steel-s-contribution-to-a-low-carbon-future.html and https://www.cdp.net/en/articles/media/steel-sector-faces-significant-losses-from-future-climate-regulation

[xix] https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-Scaling-up_Hydrogen-Council_2017.compressed.pdf

[xx] *Australian Engineers*. Poem by Henry Lawson.

[xxi] Dame Enid Lyons. Maiden speech. 29 September 1943.

[xxii] https://www.honeysucklecreek.net/40th/from_Neil_Armstrong.pdf

[xxiii] https://earthobservatory.nasa.gov/images/145332/an-eagle-takes-off-for-home