

The Transition Is Going Better Than You Think

Fred Gruen Memorial Lecture

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I'm very honoured to give the Fred Gruen Memorial Lecture today, particularly given I've had a long association with Fred's son David, including working together for a number of years. Through David, I did meet Fred a few times along the way, as well as interaction with Nick Gruen too.

I commend you to read Bruce Chapman's obituary in the Economic Record back in '97 about Fred, which is a great read. As probably many of you know, Fred was a Dunera boy, and was one of a number of those who came out on that boat who had a large impact on Australia.

Fred made a broad contribution across all aspects of economic life in Australia: obviously, here at ANU in academia, in policy making, theory, and research, as well as in educating a large number of future economists. One of his great accomplishments was in working to address the tariff issue in Australia back in the 1970s, and setting the foundations for the modern Australian economy.

One of my predecessors in delivering this lecture, John Quiggin, talked about Fred regarding economic theory as a tool, not as an end in itself, which is a sentiment that I very much share. Economic theory needs to feed into policy and have a direct translation into the economic welfare of the Australian people. Looking at what are the limits and constraints of economic theory: When is it useful, and when isn't it? And Fred also very much had the view that I come from: that the real world drives theory; theory doesn't drive the real world.

How is that relevant to what I'm going to talk about today? The economic transition is very much about practical economics. It's economics in practice. It's energy in practice and it's physics in practice, but it's also very much economics in practice. There are a large number of trade-offs in the energy transition in the real world that aren't there in theory. I am concerned that some of our approach to energy regulation and the energy transition has let the theory get in the way of the practical. For example, there are some pretty complicated pricing structures which make it hard for people to understand and to respond to those prices. While they work well in theory, sometimes the practice isn't consistent with the theory.

That said, one of the main points I want to make to you tonight is the energy transition really works in a practical sense. It is actually economic, and we're very lucky in Australia that we can be doing this transition in a cost-effective way; in a way that is not available to nearly every other country in the world. The economics of the transition works all on its

own. Even if you even put aside the climate imperative (which I'm not going to do), the economics actually stacks up all by itself.

But the main point I want to get across is that the energy transition is going better than you think. The energy transition gets a pretty bad rap. There are those who clearly think it shouldn't be happening at all and then there are those people who think it should be happening but should be happening a lot faster than it is. So the transition gets attacked from both sides. Though in my previous life, if you're getting attacked from both sides, you're probably around about right.

The general public has a jaundiced view as to how progressed we are with the transition. You generally only hear about it in ways that the transition is falling short, which projects are getting delayed, which projects are getting protested against. One of the aims of my lecture here today is to highlight some extraordinary progress that has been made in this country. The intent is to try and counter that pessimistic narrative, to highlight we've actually achieved quite a lot in the transition already. One of the other main points to get across from the practical economics that I think Fred will have appreciated is that we should be doing this anyway, even if we didn't have the existential imperative addressing climate change.

The main reason why we had to do that is in this country we had a fully depreciated energy system. It had to be replaced by something, and it's just lucky that we have a low-cost replacement that also just happens to be able to save the climate at the same time.

In making these observations, I've had a diverse experience to draw on, partly from my experience at the RBA, where I chaired the Council of Financial Regulators Climate Working Group and also was a member of the Network for the Greening of the Financial System, which is basically central banks and financial regulators around the world, which came together post Paris to focus on how the financial system can facilitate the climate transition. Then I had some first-hand experience at Fortescue Future Industries, which is the green arm of Fortescue. Subsequent to the FFI experience, I co-led with Emma Herd the sustainable finance taxonomy work for the Australian government for the Australian financial system, which gave me visibility about why funding the transition is so critical. And, for the past two years, I've been on the board of the Clean Energy Finance Corporation. I'd like to thank Owen Pascoe, Ramon Sa and the team at the CEFC who have helped me with this talk today. But let me make it clear that these are my views and not those of any of the organisations that I'm associated with.

The CEFC implements the federal government strategy for the country in the energy transition, and it gives me a direct line of sight into where the funding gaps are, what's financeable and bankable, and what isn't. In that regard it's interesting to consider that when we talk about energy generation, we're talking about core national infrastructure. Hence it's an interesting question as to what should be financed on the government's balance sheet and what should be financed by the private sector.

There's a comparison to make with roads in a number of respects. With roads, we have a national highway system, which is financed at least initially, by and large, by the federal

government. Subsequently, we've turned some of those into toll roads but, by and large, people accept that roads are going to be funded by the government because they're a core part of national infrastructure.

In the energy system, after the privatization of the 1990s into the 2000s, a lot of this is being done by the private sector, which creates some interesting challenges. Energy today is basically essential for every Australian. We cannot survive without energy. We are much more dependent on the energy generation system than we ever have been. We've increasingly moved towards a national energy generation system where every single every single item is run off energy, particularly as we move to further electrification. Interestingly, over the past few years, households have begun moving back to being more autonomous in terms of energy generation, which is creating some of the challenges in the system today.

From both the CEFC lens as well as my involvement in two large super funds, my assessment of where we are in the country today is there are funds looking for projects to fund in the energy transition, but projects have struggled for a number of reasons to get themselves into financeable or bankable shape. Part of the role of the CEFC is to try and close that funding gap or close that bid ask spread.

The Transition is going better than expected

My main conclusion today is that we really have come a long way with the transition, notwithstanding some of the self-inflicted wounds that we've imposed on ourselves along the way, which has made it harder than it than it might have been.

To frame this, let me take you back to 2008, when the Department of Climate Change was in its infancy. Among those who were involved with the Department of Climate Change back then were Jenny Wilkinson, Martin Parkinson, Steven Kennedy, and Blair Comley. Four people that have play major roles in the Canberra bureaucracy over the years.

Back in 2008 they would not have thought it possible that we would be where we are today in terms of the huge scale of renewable generation, the large decline in the cost of the technologies, and the decline in emissions. I can confirm that because Jenny told me that firsthand on the weekend. Back in 2008, where Australia first started getting really serious about this, no one would have expected the progress that we've delivered today.

While it would be nice to be more on track for the targets that we've set ourselves, we are way better than the most optimistic projections back in 2008. While we have come a long way, there are still large opportunities ahead. To some extent, we delivered some of the lower-hanging fruit particularly in the energy generation side of things. The challenges ahead are the more hard to abate sectors and I'll run through some of those challenges in those sectors later in this talk.

Importantly, to reiterate, the energy transition had to happen anyway. The power system in this country was close to fully depreciated when we started on this journey, and it's lucky we have a low cost replacement. Australia is once again a lucky country in terms of the endowment we have. We have some of the best sun on the planet. We have some of the

best wind on the planet, and often the best sun and the best wind are in the same place. This is really good from an energy generation point of view. And we have a lot of land with not much else going on it, which again is a very important endowment which a lot of people overlook. If you compare Australia to the UK, they don't have obviously have any sun(!), they do have a lot of wind, but they don't have much land.

The counterfactual of not doing this energy transition is that we would have a lot higher energy prices than we have today. That is an important point which is often overlooked. I'll present some analysis on this later on. The energy transition clearly isn't costless, but the alternatives are a lot worse.

We also have to acknowledge that there are trade-offs involved in this transition. As economists, we've got to recognize them and not deny those trade-offs and articulate them to the public. We have to address these trade-offs sensibly. We cannot let the perfect get in the way of the good. I think that's sometimes lost in the debate on the energy transition. It would be great if we could do this without causing harm to anything but unfortunately, that's generally not possible. But we've got to explain those trade-offs and explain that the economics in theory is not necessarily the economics in practice. In that regard, in terms of energy regulation and energy pricing it's often best to keep things simple. Simple is not necessarily perfect, but may be more effective in practice than the theoretical optimal.

Let me step back and take a broader view. Why are we doing this energy transition? As I said, there are practical reasons why this transition works all by itself, but the main reason why we're doing it is the imperative to decarbonise, to limit global warming, and address the consequences of climate change. Again, over the course of this year, unfortunately, we've seen the real-world evidence of what happens from the failure to do that. Even though that should be the all-powerful argument and the imperative that should override anything else, that is sometimes denied or not accepted.

But there's a strong case to make that the energy transition is worth doing in Australia, even absent the climate imperative. Renewable energy is a low-cost energy source. It is an energy source over which we have domestic sovereignty. The sun is going to shine and the wind is going to blow regardless of geopolitics. In this current geopolitical environment, that's a huge de-risking of the economy. Recent events in the Straits of Hormuz show that the ability to have energy self-sufficiency is important. That wasn't as strong a consideration in the economics calculus 20 years ago, but it is front and centre today.

The economics of supply chains are now an important consideration in thinking about things in a way that wouldn't have been true in the previous period of globalisation. Today we're seeing barriers going up right across the board in terms of supply chains, but this is particularly acute in the energy space. It's lucky that we have control over one of the most critical elements in our country's production function, namely energy. It is essential for every Australian, and more so now than any other time in our history in terms of our dependence on energy. Energy in the production function is a significant source of comparative advantage. We are very lucky in this country that we have a large comparative advantage in terms of the capacity to generate cheap and reliable energy, which is not beholden to global forces.

Where we are in the energy transition? (Graph on Emissions) This is the graph that Jenny and Blair and Martin and Steven wouldn't have believed, and particularly the very large decline in emissions from energy generation. The decarbonisation has almost entirely been in the energy generation space in this country. The other large decline is in land use and it's basically the reduction in land clearing.

Emissions in the other parts of the economy have been pretty much flat up until now. There's been some electrification which has stopped emissions from rising, but it's not made a big dent in terms or caused emissions to decline materially. That's where we've come from. But as you can see, the really big progress has been in energy generation, and I will spend some time talking about how we've gone about achieving that.

In terms of where we are going, Graph 2 shows Australia's net zero plan, and you can see that large decline. This is broadly based on viable technology as of 2025. Emissions from electricity generation just keep on coming down as we move towards the 82% renewable energy target. You can see that by the end of 2027, electricity stops being the largest source of emissions and is replaced by transport. Transport actually becomes the largest source of emissions in this country. Australia has comfortably the highest per capita diesel consumption in the world. We like sticking things on trucks and moving a lot of our stuff around the country on trucks.

The challenges are in addressing emissions in those other sectors, which I'll talk about towards the end of the lecture: transport, industrial processes, agriculture, built environment, which is basically construction. How do we get those emissions, which are flat under these current projections, to start to move downwards and reduce those emissions.

One of the other big, really good news stories, which wouldn't have been expected back in 2008 has been the huge decline in the costs of these various sources of renewable energy. There has been a large decline in the cost of solar, particularly pretty much from 2008 (Graph). You can see the comparison in terms of coal, which is much more expensive now. Onshore wind has also been on a downward trajectory, though it may be going up a little bit at the end. Utility-scale batteries weren't even a thing back in 2008. It's a new technology. The Hornsdale Battery in South Australia, first installed in 2017, great credit to Peter Malinauskas (I'm from South Australia for those of you aren't aware of that). Hornsdale was regarded as somewhat of a gamble. It's a gamble that has paid off in spades.

This very large decline in cost is another really good news story. The technological progress has been much greater than was anticipated, and we've really moved down the cost curve. There has been a lot of positive surprises.

As a result of the deployment of solar, wind more recently and now batteries, in the 2025/26 financial year, renewables accounted for 45% of all demand for electricity in the NEM. At the end of last year, we hit 50%. In October, November, and December at the end of last year, renewable power was responsible for 50% of energy generation in this country, and we've basically stayed there or thereabouts. In October last year, for a period of half an hour, renewable energy across the NEM, accounted for 80% of energy generation. South

Australia's gone for long periods of time where it's been 100% net renewable generation,. South Australia has a goal of being 100% net renewable by the end of next year. They're very much on track to achieve that. Again, this story doesn't get enough publicity. The story in WA in the SWIS, which is the network in the bottom part of the state (Perth basically), is also very similar with rooftop solar and batteries playing an increasingly large role. The Pilbara is an interesting story and probably worthy of a lecture all by itself

We've had this huge deployment of renewables in terms of grid-scale generation. The installation of all that renewable generation has clearly come along with a large increase in investment spend. I did some work with Toby Phillips at the Centre for Policy Development on this a couple of years ago. The point we make there is if this cost of this renewable s deployment to hit 82% is around \$600 billion. That's the estimate we came up with a couple of years ago. I don't think it's much different from that today. While some components have got a bit more expensive, others have actually got cheaper and batteries are particularly a lot cheaper.

Toby and I emphasised that much of that \$600 billion was replacement capex, replacement capital expenditure. As a country, we were going to have to spend this on energy generation anyway. We had a fully depreciated generation system. It was built in the 60s and 70s and into the early 80s, and it had reached end of life. This point is greatly underappreciated.

Most of the cost of the energy transition is money we were going to have to spend on a new energy generation system anyway, be it renewables, be it more coal-fired power station, be it nuclear, or whatever. The energy generation system needed to be replaced and upgraded regardless. We are very lucky in this country that we had a low-cost solution in the form of renewables, as I showed on that graph a minute ago. Solar and wind has lower cost than coal. We are lucky we are endowed with the capacity to generate cheap renewable energy.

One of the challenges is that we're not installing the new solar generation and new wind generation where there are existing transmission lines. So we have to spend money on transmission lines. The best solar and the best wind is not always proximate to the existing grid. There is a trade-off to be made by saying, I'm going to install it closer to the grid where the solar and the wind generation capacity is not necessarily as good, and you have to work that through the project economics. (Graph on Transmission network).

It's reasonable to say that's an additional cost coming from renewable generation rather than just standing up, in a very expensive way, more generation on the existing coal-fired generation sites. We do need that transition and that transmission. One of the challenges we have at the moment is until that transmission is in place, we're spilling or curtailing a lot of electrons, that is wasting a lot of electrons.

One of the other interesting things about transmission is the utilisation rate. If you think from an economic point of view about capacity utilisation rates, normally you are not thinking about more investment when your capacity utilisation rate is in the 40s. The utilisation rate, on average, of our existing transmission is in the low 40% . Clare Savage, who's head of AER often makes the observation that it's interesting that we're spending all this money on additional transmission when utilisation rate of our existing transmission

system are in the low 40s. Hence one of the other things we're doing at the CEFC is trying to see what can be done to increase the transmission utilisation rate, which is basically the capacity to send more electrons down the existing lines

One of the other things we've got to do is be better at matching demand and supply at the local level in the grid. I'm going to come back to that in a little more detail shortly.

With the old energy generation system, the big coal-fired power stations were pumping out electrons, one-way traffic down the transmission line to the users. Now we've got electrons wanting to go both ways. Households, in some parts of the day they want to consume those electrons; in other parts of the day they're generating those electrons. The energy generation system, and the pricing in particular, is fairly indifferent to where those electrons come from. Now we've got much more capacity for local area networks.

We've got the capacity to generate a bunch of electrons, and the users of the electrons are just across the road or just around the corner. Again, it affects the utilisation rate of the existing transmission. It wasn't the way the system was originally designed. In 2010, the NEM had 26 coal-fired power stations generating about 30 gigawatts of power. Today we're down to 15 coal-fired power stations generating around 21 gigawatts of power. In the meantime, we've stood up 34 gigawatts of grid-scale renewable generation.

If we could even find someone able to build a new coal-fired power station today, it would be a considerably more costly investment than any renewable generation to generate those 34 gigawatts of power. I'll pre-empt the nuclear question before someone asks it in the Q&A. There's an interesting story in the Financial Times again yesterday about a whole bunch of nuclear fusion startups in the U.S. who are struggling. One day someone might be able to solve nuclear fusion at scale. It's always been just around the corner for about the past 50 years, and it's still supposedly just around the corner today. We can't wait until that technological challenge is resolved. In the meantime, we have a low cost solution in the form of renewables to rebuild our depreciated energy generation system. Happy days! Lets go with that.

In terms of the cost savings from renewables, there's a number of thorough counterfactual analyses. One piece I'd highlight is from Simhauser and Gilmore a few years ago now, and another more recently from Jacobs, the engineering company.

I realise there are often problems with the public understanding counterfactuals. The public have some distrust that you're gilding the lily. I've experienced some of that firsthand in my previous working life. It's hard to explain to people that the fact that we did all that monetary stimulus and fiscal stimulus in 2020 when COVID hits meant that they didn't lose their jobs. Most people think they didn't lose their jobs because they're good at their job, not because of the economic support and stimulus put in place.

Putting that aside, the counterfactual analysis says that we would have had 30 to 50 percent higher energy prices today than we would if we had not been able to install this renewable energy capacity. That's a big number. Moreover, the work was done by Simhauser and Gilmore about five years ago. Today, coal and gas prices are considerably higher than that

and at the same time, renewable prices have declined further, so their number is an underestimate of what the savings would be today

This is a great news story. Households and businesses in Australia are today experiencing energy prices 30 to 50 per cent less than if we hadn't undergone this energy transition.

One of the big challenges we have today, and this highlights that we've done the easier part and the harder part lies ahead, is how do we get that additional generation capacity in place? One of the big issues we have today is around the uncertainty of timing of the retiring coal-fired power plants. In addition there is the imperative, the political imperative at the very least, but probably an economic one, to have 100% energy reliability. It's not very good if we say, okay, unfortunately, that coal-fired power station's just fallen over. We're going to be without that energy for the next couple of years until we stand up a replacement. That's not going to work and reasonably so.

We've got to stand up the renewable generation capacity ahead of those coal-fired power plants retiring. That's a challenge because of the uncertainty about when they're going to retire, which also affects the difficulty of estimating future prices. There's uncertainty over what the future supply is going to look like. The supply increases in large steps, not incrementally (with the exception of rooftop solar). There's also uncertainty over the demand, and that makes forecasting future prices challenging.

There are a few ways to help address that. One is to have long-lived power purchase agreement with a big energy buyer that gives you some pricing certainty for your generation project. Otherwise you have merchant risk because you just sell it into the market at whatever the price is on the day. By and large, merchant risk for an energy generation facility is not bankable. Banks won't finance it. Super funds won't finance it. They don't want the risk. They want more certainty of what your future revenue stream is going to look like.

While increased electrification implies energy demand should rise, at the same time we're also getting more efficient in using energy generation. So there's uncertainty around how much increased demand will boost future prices, but the big uncertainty is around supply. There's a bit of a catch-22 here, and we don't unfortunately have a Walrasian central planner in this system. The ISP, our integrated system plan produced by AEMO, is not the Walrasian central planner.

This uncertainty comes with a cost. There is a question as to who underwrites that cost. The Capacity Investment Scheme goes some way to try and do that. Another way to do that is by having a very large source of additional demand, enter data centres more recently, or large industrial facilities like Tomago. To give you an idea of the scale of data centres, Tomago by itself accounts for about one gigawatt of energy demand each year, so pretty a big factor in the NEM, where the total is somewhere between 50 and 60 gigawatts currently. Anthropic's new data centre that they announced yesterday is five gigawatts all by itself. So one company, one data centre, five gigawatts. That's a big number.

The other thing that we need, ideally, from a very large energy user like that, is a degree of flex. That is, they don't need that power all day, every day, and they can adjust as the supply

of energy fluctuates. In New South Wales the recent data centre policy requires that if you want to have a fast track assessment, you need to have a degree of flex in your energy demand of plus or minus 25%. So in Anthropic's case, their degree of flex would be the size of Tomago's total energy consumption.

One other interesting challenge around data centres is there's a latency, to use a data centre term, between the time it takes to build a data centre and the time it takes to build new generation. It might take a couple of years, if all things go reasonably smoothly, to build a data centre. Energy generation, on the other hand, if you're doing well, it's somewhere between four and six years. In particular it's four years from connection to full output on average for your standard wind and solar generation facility. So if we're standing up these data centers in the next couple of years, the energy generation is going to be coming along a fair bit behind, which is an interesting issue.

It is also worth considering new generation projects in terms of their basic project economics. One of the big constraints in energy generation is the time to build, particularly the approval process. If you think about from the project economics, one more year that I have to wait to get my project approved is one more year without revenue. In any discounted future cash flow model, that has a first-order impact on the project economics, particularly if that one year becomes four years or five years. So that's one of the big challenges in this space: the time it takes to go through the approvals process really has a first order impact on the project economics.

Coming back to my road analogy, I find it interesting that the social license which is applied to new generation facilities, is often not applied to roads. There seems to be a lot more challenge and a lot less acceptance about having generation on my land - or not necessarily on my land; people are more willing to have it on their own land, it's more when it's on their neighbour's land that they particularly don't like it. Even more so with transmission.

I find the analogy between transmission and roads interesting. When the government wants to build a road, that's where the road goes. That's not the case with transmission. That said, in northern South Australia, the new transmission projects don't often have so many challenges because they just don't have to deal with as many landowners. Whereas with transmission in Victoria, a large number of communities are directly affected by the proposed new transmission.

Most new generation projects are, by and large, greenfield projects. They're not zero damage, we have to recognise there are trade-offs. It's much easier to oppose an individual project because it's the concrete example, whereas it would be okay if it were somewhere else. But if it's not here, then where should be the response. We have to recognize those trade-offs because it's easier to oppose the concrete proposition rather than the nebulous alternative.

So there are challenges around the electricity price for the new projects, and we've got this challenge around time to build on the new projects. Another challenge we have is around supply chains. These projects require key components like transformers, for which there can be long waits on the supply chain. I think there's an interesting thing to think about from a

national security point of view about having a stockpile. We have a fuel reserve stockpile. For similar reasons we could contemplate having a stockpile of key components like transformers. We know we've got a lot of these projects coming down the pipe, the wait on the supply chain is quite long for some of these key components. But we know we need these components across a large number of multiple projects. Hence we could have a national stockpile of key components to supply them to future projects.

So far, I've been talking about providing generation to meet the existing demand for energy and the expected future demand under the existing economic structure of the country without thinking about export opportunities. We have the capacity to produce an abundance of low-cost green electrons. The question is, what do we do with them?

Coming back to the electricity price question, one of the challenges we have, as I said before, is getting a price which makes new generation attractive, but at the same time not being so punitive to the users, particular households, but also businesses. Similarly, there's a sweet spot in energy pricing in making exports economic, but also making generation economic. And again from the financing point of view, there's the problem of the market's unwillingness to finance merchant risk.

Returning to the question of how could we actually export these green electrons, presuming we can actually generate them. In what form should we export them? Possibly not an electricity cable to Singapore anymore but maybe a data cable to Singapore. Are we going to export these green electrons in the form of tokens? Green iron, which embodies those green electrons is another potential source of export, and while the economics of that is not quite there yet, it is becoming more and more so by the day. It might be in the form of something like green ammonia. But we do have the challenge though of getting a price which works for the exports, works for the domestic consumption, but also works in terms of encouraging the new generation. And as I said, we don't have a Walrasian central planner to sort all this out for us.

Having talked about generation for some time, let me turn to the other big positive surprise, namely storage. Back in 2008, when the Department of Climate Change, storage wasn't even really a thing. Now it's a really big thing.

In the last year, households have installed 13 gigawatts hours in one year. That's more than the US has put in place in its whole existence. So in one year, we've done more than the US a country 10 times our size has ever done. Hornsdale was a big battery back in 2017, and was the only industrial scale battery in the country for quite some time. Now it's a relatively small battery and we are adding many more Hornsdales. We have a huge increase in utility scale storage capacity in prospect. (Graph).

Turning to household batteries, the graph shows the large but gradual rise in rooftop solar since 2008. The takeup of batteries has been parabolic. The graph shows the 10 gigawatt hours of batteries we've installed over the past year. This surge in battery installations was just completely unexpected. If you go back to AEMO's previous integrated system plan a couple of years ago, it didn't have this in the plan at all. It does show that incentives actually

work. They sometimes work a lot better than you expect. The large take-up in household batteries is starting to flatten the duck curve.

There's also been a big surprise in the household sector in terms of energy efficiency as well. Energy demand from the household sector has tended to go down, even as we're electrifying more, because things are becoming a lot more energy efficient.

The consumer energy resource side of this is a big thing all by itself in terms of energy generation in a way that you just would not have anticipated back in 2008. Today 43% of detached houses have rooftop solar in the country. A big challenge now is dealing with apartment buildings, but we're making progress on that and there is also the rental market. Around 70% of Australian houses are owner occupied. 30% are rental. So that 30% is a big chunk of the housing stock which, by and large, doesn't have rooftop solar.

This is a challenging equity issue: the differential between owner-occupiers and renters, and between detached houses and apartment buildings in terms of rooftop solar and batteries. There's an equity challenge here about how do we share the gains because some households are able to install their batteries, install their solar panels, and there's a bunch of households who can't and are still completely reliant on the network. A number of households are basically being able to take everything behind the meter and pretty much take themselves off the network for large chunks of the year.

We are moving away from a network and losing the advantage of being a network. The more households that take themselves off the network, the less you're able to generate network benefits. So that's an interesting, interesting challenge. As I said, particularly as it applies to renters and to lower income households, which are often one and the same thing.

Just recently, the government announced a program to encourage solar and battery take-up on the business side of things. When Minister Bowen announced this, he noted that when you fly into Sydney Airport, you see a lot of warehouses in Botany, big flat roofs with no solar. Hence there is large potential for energy generation there.

There are a few challenges to work through. Sometimes the people with the big warehouse roofs aren't big energy consumers. They're not going to need it themselves. However, there's a facility somewhere in the general neighbourhood which is a big energy user, which would want to use that solar energy. This is certainly the case in Botany. But again, the network wasn't really set up to have a local area network. So the power which is generated by those warehouses can be used by an industrial facility just down the road but how do we get that power to them.

The local council may not like digging up the street to put in a cable linking the producer of electrons on one side of the road to the user of electrons on the other. There are ownership challenges as well: between the owner of the industrial land which may not be the same as the company, who may more likely be a commercial tenant. Who actually owns the solar panel? The commercial lease may only run for five years, but the solar asset has a life and payback period which is longer than that. These are challenges but they do seem solvable ones.

And to repeat, while we have energy demand and supply in close proximity, the network isn't actually set up, and the pricing isn't set up, to handle that. If we were able to do that, we'd need a lot less transmission as well. It comes back to my earlier point about the utilisation of the existing transmission network. The electrons only have to go a few 100 meters rather than hundreds of kilometres. It's a much easier journey for them, and potentially much less costly.

More generally, one of the challenges we have is that we now have all these decentralized participants. The electricity energy system is a network, but we've got all these decentralized participants, and so we lose a lot of benefits of the network system. And as I said earlier, another problem was the system was set up to be one-way flow of electrons, the generator to the user, not electrons going backwards and forwards down the same piece of line.

I appreciate why we privatised all the parts of the energy generation system back in the day. However, that has probably not been very helpful for managing a big wholesale energy transition, specifically having a large number of decentralized players with often quite different incentives. There's a lot of different incentives between a retailer, a generator, another who's responsible for the network between the two. If I'm one of those participants, I'm not necessarily going to do investment if I'm not sure who's going to reap the benefits. If I own the whole system, I know the benefits are there for the system as a whole, and I'm reasonably indifferent as to how that lands. But with many participants at different parts of the energy generation chain, they want to capture those benefits themselves, and they're not guaranteed of doing that. That makes the willingness to do this investment more challenging.

However, I want to go back to the positive, which is the generation story has just absolutely blown the lights out of what we would have thought of 12 years ago, even two years ago. Through this take-up of rooftop solar, we are generating way more zero emissions electrons than we ever would have thought possible back in 2008. We are very well progressed on that.

But as I said, we've done the easier part, and the challenge to get to where we need to is going to be probably going to be harder from here, at least from the pricing and the project economics point of view.

I think the other thing to think about is that we have that 82% renewable energy target, and I'm used to missing targets back in my old life. But in this case, actually, if we don't quite get to 82%, that's not such a bad outcome. The fact we are 50% today is a big achievement in and of itself. If we get to 82% a couple of years late, that's not that bad a miss. It's much probably even a much more benign miss than even missing the inflation target. The 82% target has been a very useful marker but we need to celebrate the fact that we've actually managed to get to 50%, and we're on a plausible path to get to 82%. Even if we miss by a bit, miss by a year or two, or miss by a few percent, that's not a bad outcome. We will have delivered most of the benefits of what we want to achieve.

The good news story is really on the generation side of things, and we've really achieved a lot there, and at a lot lower cost than we thought we were going to. We've been able to replace an energy generation system in a cost-effective way, which has delivered lower energy electricity prices to users and particular households. In that context, post-Iran electricity prices have actually fallen in Australia. In almost every other part of the world electricity prices have gone up a lot because of the impact of Iran. We've been able to insulate ourselves from that here, which again is a story which often gets lost.

Now let me turn to what are we doing in decarbonising the other parts of the economy. One of the main things that's occurring is electrification. But there are easier parts of the economy to electrify and harder parts to electrify. In transport, we've obviously seen in the past few months massive uptake in EVs from households. Also, in smallish trucks EV penetration is increasing. Your local delivery truck is likely an electric vehicle. Heavy vehicle transport, though, is a much larger challenge and we use a lot of heavy vehicles in this country. As I said earlier, Australia has the highest per capita diesel consumption in the world. I drove down the Hume to get here today and have been up and down the Hume quite a bit in the past couple of weeks. There's a lot of heavy vehicle transport on the road. We do like putting stuff on trucks. There's a modal question as to how much we can shift off trucks onto other forms of transport. But then there's then there's potential for electrification of heavy vehicles.

We spent a fair bit of time looking at this when I was at Fortescue. The Hume Highway actually lends itself quite nicely for electrification because the trucks are driving known routes by and large. So if you had a facility in the northern suburbs of Melbourne around Craighburn, and something in the southwest of Sydney in terms of battery in/battery out for heavy vehicle transport, then the economics can actually start to add up. I think this is one area where we're likely to be surprised on the upside from the technology side of things because China is investing a lot in this space. We've seen the impact of that in the passenger vehicle market in terms of Chinese vehicles coming into the country. I think we're likely to see that in the near future on the heavy vehicle side. So, in our case, dealing with trucks is a big challenge. I said there's a modal question: do you shift off to other forms of transport, or do you electrify what you've got?

Air travel is another challenge. At CEFC we're very much looking at low carbon liquid fuels. Again, we're lucky in this country; we have the capacity to generate this stuff or to grow this stuff. If you drive up and down the Hume, you can see the canola crops. Transport, as I said, is going to be the number one emissions generator in this country in the very near future, so that's the challenge we need to lean into. Shipping is another one as to what the potential solutions are. At the moment, it doesn't look like sticking a battery on a plane is necessarily going to work for the physics of it, but there is progress happening in that space. At the moment, it more looks like a low carbon fuel solution.

This is an area where not letting the perfect get in the way of the good is important. Low carbon is not zero carbon, but there's a lot less emissions than the current fuel, and so you can make substantial progress by moving down that path.

There's also an interesting question between the green premium versus the black discount. We often talk about the green premium. If I want to go green, I have to pay up for it. It costs me more than my current alternative, which is because we don't price the externality of the current fuel source. I think it's much more appropriate to refer to it as the black discount rather than the green premium. The green premium fully internalises the externality in a way that the black discount doesn't. My fossil fuel does not internalise the externality that I'm generating from using it, and that makes me less willing to pay for that green alternative. This is why demand-side incentives to address that are necessary. Moreover, the green alternative may be near the top of the cost curve, and as you develop it, you're likely to move down. We've seen that play out any number of times as you move to scale, and as you learn out how the technology actually works.

Transport is going to be our big challenge. However, there are solutions out there which are starting to become more and more cost-effective. Turning to Resources, this is where something like green iron kicks in. To give you an interesting example on green iron, with Whyalla, (this is not being parochially South Australian). Whyalla has an interesting combination of having the iron ore there, just to the north of it. They have a very large potential source of renewable energy just to the west of it on the Eyre Peninsula. They have an existing port and they have an existing workforce. There's a great combination of inputs there which can make green iron viable.

In terms of iron ore, the Chinese reduce iron ore primarily with coal, which is the source of the large scope three emissions for Australia. If you move to a gas solution, it reduces your emissions by around about 60% while if you reduced the iron ore with electricity it reduces emissions by 90+%. That's a sizeable reduction in emissions on the way through to full electrification, which is interesting to think about.

In terms of industrial processes, a lot of the challenges there are they require a huge amount of heat, and the question is how are you able to generate that heat in a non-carbon intensive way. To a large extent that's a physics problem, which we are still in the process of solving. Cement's another good example. There are various processes out there to make low-carbon cement, but it's still proving challenging to do it on an industrial scale. The projections for emissions in this graph are based on known technology, and so hopefully we will see upside surprises in a number of these areas as the technology evolves over the coming years.

In the resources sector, we are seeing increased electrification of many of our mining sites, particularly up in the Pilbara, and also installation of solar and wind, because there's a lot of good solar and wind up in the Pilbara. We are gradually making progress there. CEFC has done work looking at rewiring the Pilbara. One of the big challenges there is how you deal with common use infrastructure.

The built environment is another large sector of the economy to focus on. Cement, as I said, is one of the big challenges. Also, from a circular economy point of view, every time you rip down a building that releases a whole bunch of carbon into the air, and we're not very good yet at reusing a lot of the materials. We're starting to make progress on that, but there's a fair way to go.

Agriculture is another sector. Cows are responsible for a sizeable share of those emissions, and that's a challenge. Technology is working on that. In terms of land use and regeneration, we are making progress on that, including with natural capital, where the CEFC is active. We are seeing increased electrification on farms. They are again realising that electrification is a cheaper form of energy than diesel, and so we are seeing that being taken up.

All of these are areas that the CEFC is focusing on in terms of making a big dent in our emissions progress. The CEFC doesn't need to participate so much anymore in electricity sector (with the exception of transmission) because the economics by and large work, notwithstanding some of the challenges I talked about earlier. It's in these other sectors of the economy where there's more need for incentivisation.

Those challenges are what lie ahead, but we shouldn't lose sight of where we've come from. We have come a long way, and there is a plausible pathway to achieve our emissions reduction objective. That doesn't mean it's going to be easy but our 2030 target, our 2035 target are actually achievable. Those targets are helpful, but if they are missed, that's not a disaster. If we're broadly trending in the right direction, if we miss by a year or two, it's clearly better than if we hadn't made all that progress.

Compared to where we were in 2008, emissions reduction is so much better than we expected. Bob Gregory and I were talking earlier about the early 90s inflation experience. We had inflation in the 1980s around eight per cent and then we managed to get it down to two. People were concerned when inflation rose back up to around three or four per cent in the mid 1990s for a little while and there were claims the inflation target wasn't working, but that's a better outcome than when inflation was at eight year in year out and the misses proved only to be temporary. The emissions targets are somewhat analogous to that as we've actually made a really big dent in our emissions, and while we may not hit the target that we're aiming for (although I hope we do, and there is a plausible path to achieve that), it's not a disaster if we do miss by a bit or get there a bit later.

We've focused a lot of our attention so far on the supply side and incentivising that. We've got to think more about demand side activation and thinking about the green premium versus the black discount. The semantics do actually matter here. In the discourse, it actually be better if we talk more about the black discount: the fact that the fossil fuel alternative has the cheaper price because it's not internalising the externalities. Premium carries the connotation of being excessive which is not helpful.

It's also not a Field of Dreams world. It's not the question of if you build it, they will come. They may not come in because the ticket price at the gate is too high. So we've got to address that ticket price at the gate to actually get people onto that field of dreams.

One of the big upsides surprises we potentially have ahead, just like we had with the household batteries over the past couple of years, is in the business space in getting that solar generation on those warehouse roofs. But then also dealing with the challenge of getting those electrons to the users, which may be just down the road.

Technological progress is very much happening in this space. Larry Summers talked a lot about secular stagnation. We are not in a world of secular stagnation in the world of the energy transition. The technological progress that has occurred in this space has been massive over the last 20 years and I think there's a large source of upside surprise to come. I think large vehicle electrification is probably a decent bet here.

But trade-offs need to be made, and we can't achieve perfection in this. We can't do no harm. Many of the projects are greenfield projects, and those, by definition, come with some degree of harm. It often seems to me the green projects carry even more baggage than other projects in terms of having to overcome that, and so we've got to think about harm minimisation, not elimination. We can't let the perfect get in the way of the good.

The other challenge we've got is producing a plentiful supply of electrons in this country because we have the potential to do it. But how do we generate those? How do we make it economic to do that generation of those green electrons? We can be the green energy superpower. But we are not Dorothy in the Wizard of Oz, and we can't just click our ruby heels and wish ourselves back to Kansas. We can't click our green heels and say green superpower and be there tomorrow. It's a journey. It does require an effort to get there.

A huge opportunity lies ahead, and we are very much at the cutting edge of this. We have the best behind-the-meter technology of any country in the world, because we have had to because of the renewable penetration we have in our household sector

We've also seen a massive de-risking of the economy. That's another really good news story. Energy is such a critical part of the economy. We have one of the world-class endowments to be able to produce that energy in a cost-effective and climate-friendly way. We're very lucky to be able to transition from one form of energy to another.

We need to be telling that story. We need to be shouting from the rooftops (while dodging all the solar panels up there) that this has actually been a really good news story, which has delivered lower energy prices than otherwise would be the case. As economists, we need to be explaining those trade-offs. Like I learned when I was talking about monetary policy, you need to say it once, you need to say it again, and you need to say it so that people are absolutely sick of you saying it to make sure that the message gets through.

Finally, as some of you may know, I tend to use music quotes in my speeches. I've saved it right till the end. I'm going to use Fatboy Slim this time and say: we've come a long, long way together through the hard times and the good. I have to celebrate you baby, I have to praise you like I should.

We should be praising the transition in this country, because it is actually a really good news story.