Benjamin Hickey: As the climate crisis heats up solar power is a crucial part of the renewable energy mix. But while solar technology is getting cheaper and more effective detecting defects in solar cells is a difficult and expensive part of the panel manufacturing process, until now. My guests today have worked out how to spot these defects in fractions of a second. Transforming the industry and helping reduce the costs of solar energy. They've also founded a company to spread the technology, BT Imaging, which has now sold products to almost every leading solar panel producer in the world. I'm Ben Hickey from the Australian Academy of Technology and Engineering and I'm talking to Academy Fellow Professor Thorsten Trupke and Adjunct Associate Professor Robert Bardos. They are based at the University of New South Wales School of Photovoltaic Renewable Energy Engineering and have just won the Clunies Ross Innovation Award. Welcome Thorsten and Robert.

Benjamin Hickey: So, how does this technology work and what was your process of developing it?

Thorsten Trupke: So you can imagine our technology is comparable to an x-ray machine. You know when you go to the dentist you get a black and white picture and the doctor can very clearly analyze that and tell you what's wrong with you. Something that you cannot see from the outside and in the same way what we have developed is an imaging technology that is based on the photoluminescence imaging principle. The beauty of that is that it can detect a wide range of defects and that includes material defects with the crystalline silicon material itself but also devise specific problem that occur when you turn these silicon waves into solar cells.

Thorsten Trupke: Contacting problems and a very wide range of problems and the benefit of this technology is, as you said, it is extremely fast. Similar technology that would be used to measure those defects and get information about their spatial distribution would take typically seven hours for a single sample. What we developed enables now to take similar measurements or you can hire quality data in a matter of seconds. This is obviously very useful tool for the researchers, the people who work on the developmental solar cells. Back in 2005-2006 when we first demonstrated this technology here at the University of New South Wales it really spread like a bushfire here in the center because people immediately saw the benefit of this technology for their own work.

Robert Bardos: To give you an example, people would see tweezers marks on solar [inaudible 00:02:38] they were processing and they had previously not known that the tweezers did anything. They even saw finger prints sometimes. Any kind of machine that handle a [inaudible 00:02:46] would potentially leave some contamination which led to lower device quality. Previously they had no way of resolving that spatially and all of a sudden they saw an image, we showed them exactly what was causing their problem. So it caused a lot of excitement at the time.

Thorsten Trupke: Yeah, so you got to imagine that making a solar cell is a relatively complex time consuming process that takes, when you do it here in the lab several days. Back at the day all they would get is the overall efficiency of that solar cell without much quantitative information about what is actually limiting it. Our technology can be applied before and after each process step. So you can actually quantify and see exactly which of the process causes specific problems. The academics back then who were working here on the development of solar cell technology this is absolutely priceless, Jeff Kolta, one of our colleagues back then every measurement is worth $10,000 to me because it saves my researchers so much time and effort going down the path of failure, if you know what I mean.

Benjamin Hickey: So what will that mean for the implementation of solar technology?

Robert Bardos: Well, we've had leading researchers tell us that from large solar companies trying to tell us that they couldn't have done the research and the development of their cell technology that they have without our technology. That it was absolutely crucial to their success.

Thorsten Trupke: Another example is as we have seen, technology constantly evolves. Researchers are constantly trying to do new processes or new devices in order to bring down the cost and at the same time improve the efficiency of these devices and sometimes they get it wrong. A couple of years ago there was a push towards so called CasMono which is specific type of growing the silicon wafers. It turned out, while it sounded like a good idea, it did result in a dead end. Our technology helped tremendously with them figuring out that the technology they were trying to develop would never work. Then they moved on to something else. In that sense our technology is really crucial in terms of helping the research and development process.

Robert Bardos: When the technology was first released at a trade show in Valencia in 2008 there was practically a stamped to our booth from every solar cell manufacturer. We had competitors, we had to tell them that the time was so limited that that couldn't have a private viewing of their data. They had to tour it. Competitors being able to see images of their material on our machine cause we just couldn't fit them all through any other way. it was an astounding thing to see direct competitors happily agreeing that they have their data seen by their competitors because they just wanted to see what this machine could do. it was an astonishing experience.

Thorsten Trupke: Exciting only [inaudible 00:05:24] it was a that time, he in the labs everyday researches would come with some samples put them into our imaging tool and then we would look at the image data and they'd be astounded and say this is fantastic that I have found this problem. New discoveries every day back then.

Robert Bardos: That's why Thorsten compared it earlier to the x-rays because if you imagine medicine before the x-ray you might have a sore arm but no idea why. Suddenly x-ray enabled the doctors to see you have a broken bone or not. It's the same

with our machine it's like from the outside you can't see what's wrong with the cell but Pol machine gives you essentially an image of whats going on electrically inside the cell, all the wafer.

Benjamin Hickey: That's incredible. So it's one thing to make these amazing discoveries but you have also been extremely successful at commercializing them and spreading them across the world. What was that process like?

Robert Bardos: Well, yes. We knew nothing about how to do that at the beginning so it was a very steep learning curve for us. There was three parties essentially. There was the University, there was ourselves and then there was potential investors. It did take a long time to make that work. And in the end we did involve an advisors to negotiate on our behalf, that really was what caused link jack to clear. Because they had the expertise and credibility to negotiate the final deal so we found that through non commercial background the process got stuck and it was resolved when we managed to convince someone with lot more experience than us to negotiate on our behalf. then things worked much more smoother i guess if we had identifies that aspect earlier things might have happened quick. That's why we advice people now that they have to find an experienced person to advice them on how to go about commercializing their technology in order to that they can get a suitable return and the other party as well get a suitable return.

Thorsten Trupke: When you say extremely successful its all a matter of perspective i guess. at this stage we have been in business for 12 years which is a great success for us but we are still a relatively small company. 25-30 people. most of them located here in Sydney . we have been indeed very successful in driving this technology into the industry in terms of laboratory tools so pretty much every solar maker every wafer maker and every research institute is using our technology so if you go to conferences these days you see these peer images everywhere. What we haven't been very successful with is driving the technology in to the real home of manufacturing. we have started that process there is a couple of companies using our tools in manufacturing to give you an idea these imaging system measure 8000 panels per hour That's two and a half dufpanels per second they go really through go like a cookies factory and we measure these high resolution PL images including algorithms and data analysis. What we are hoping to achieve is that we find the value proposition for this technology for inline manufacturing in full scale production because that would really be the breakthrough for our company cause it would lead to a very large increase in our sales and revenues.

Robert Bardos: Another thing we are turning to now in the downstream market which is installed modules. Australia is becoming a very large player in this space, there is a very large [inaudible 00:08:41] being installed in Australia. Previously we have worked upstream with ingots and wafers and cells but now we are concentrating more on modules because those are huge install base in Australia and other western countries. That's a very attractive market to look at.

Thorsten Trupke: I was actually asked about this, this morning. People figure out that some modules which have come to Australia for example which are not up to standard. The reason for that is the manufacturing of solar cells and solar modules is a cutthroat business. It's a low margin business mostly carried out in China. I guess there is always some cowboys in this industry who take short cuts, use low quality materials. The modules of course are meant to last and keep their performance up for 25-30 years. They actually have a warranty for that period. Recently there was a media reports which failed after serval years, only a handful of years. That is going to be more important issue for companies like us to drive approaches where modules that are coming into the country are monitored on a regular bases so that Australian consumers are protected.

Thorsten Trupke: Don't get me wrong, The vast quantity of these modules are high quality but there is always a small number which are bad and it's important we are able to weed those out.

Robert Bardos: Our supplier will have a distribution of results from their production. If they know one customer or even one country has very slack standards or no standards, then they are more likely to send less good products to those countries and more likely to send the best products to the customers or countries which have told them they are going to perform certain inspection test on certain fraction of the modules or etc. etc. The tighter the process is the more likely you are to get the best product. It makes perfect sense. So for example you could say the exact opposite is the pharmaceutical industry where it's extremely highly regulated. This very little likelihood of you being shipped a bad product. Solar is a very new industry, there is no worldwide agreement on what the correct standards are, so many competing standards that it's very confusing. There is a lot of work to be done in this space.

Thorsten Trupke: It is important to note that, as I said, vast majority of modules are high quality. And will last for 25-30 years, no problem. We are not suggesting that there is a fundamental issue with using solar energy for large scale electricity generation.

Benjamin Hickey: Yeah, fantastic. It's a very exciting space. So on that, what role do you think Solar plays in the role of future energy generation especially in the face of climate crisis?

Thorsten Trupke: I guess both Robert and I agree that Solar energy will take over. There is actually a revolution started, and that revolution will see a transition from burning fossil fuel using renewable energy sources. Solar is by far the biggest potential for using renewable energy, especially in a country like Australia which is really a prime target for large scale Photovoltaic power plants. The big issue is that not many people are aware that the prices for these solar panels have come down dramatically. In the last ten years alone the prices have dropped down by a factor of 10. Solar panels are now so cheap that you can calculate the so called [inaudible 00:12:05] cost of electricity which is effectively how much does it cost to generate one kilo an hour. In many countries in the world Solar is now the

cheapest option. Cheaper than coal, cheaper than gas and certainly cheaper than nuclear. That trend is almost certainly going to continue, Solar will continue to get cheaper. Rest everything is going to get more expensive.

Thorsten Trupke: To my mind it's almost certain that by 2050 worldwide 70-80% all primary energy being generated by renewable energy sources and off that a large percentage will be solar. Which is an exciting prospect I keep comparing it to the old steam train, the way we look at a steam train today we go 'oh look it's funny, blowing this steam out of the chimney'. Our children will look back and say 'oh look how silly were they, they were burning coal to generate electricity. That's completely silly.' World will see a radical transformation of how electricity is generated, how it is used and how it is distributed. That will happen worldwide, this transition.

Robert Bardos: So it is worth pointing out that the discussion in Australia is misguided. It is portrayed as if we have to chose between taking action on climate change which will damage our economy and not taking climate change which won't damage economy. But recent work by Martin Green has highlighted the fact that there is actually a resource export bonanza awaiting Australia due to the Solar energy because Solar panels are not made of fairy dust. They are made of metals and glass and silicon, the amount of steel, aluminum and copper to build a terra watt of solar panels is worth about $8 billion. So to export one terra watt of solar panels to be built requires from Australia alone $8 Billion worth of mineral export.

Robert Bardos: Let's say in the next couple of decades, while the worldwide solar capacity is being ramped up, there would be an export bonanza for minerals from Australia which will more than compensate for the reduction in thermal coal. This has simply not been understood. The thing is that the transition to renewable will be driven by economic factors regardless of climate policy, because as Trosten mention it's now cheaper. The question is do we want to accelerate that process to address the climate issue which is all of our interest. We can invest in research and development, invest in planning, so that the [inaudible 00:14:33] is in a coherent fashion and they connect to the grid properly. But the process itself is going to be driven by simple economic factors and will happen regardless of the policy.

Thorsten Trupke: The other thing that we did not mention is that Australia really is an absolute position to become a global PV powerhouse. We are already are powerhouse in research and development especially here at [inaudible 00:14:56] . Australia is the perfect country to install huge amounts of solar. There is vast amounts of empty space with plenty of sunshine. There is technology that exist to distribute that country to other countries for example there is high voltage DC lines which are economical in the future as solar becomes cheaper and cheaper. There is opportunity for actually turning solar generated electricity into liquid fuel, hydrogen, I don't know that the details are going to be but one thing is clear there will be a time in the not too distant future where solar generated

electricity is going to be virtually free. That will open up a huge space for new applications.

Robert Bardos: One of the application is leveraging Australia's very large resource industry. So at the moment we export a lot of unrefined ores. But when electricity becomes very cheap and available in huge quantities in Australia, the economics of doing refining of ores in Australia will become much more attractive. So the ability of Australia to value add to the primary production of mineral ores will boon to the economy. In future Australia will be a resource based economy the same way it is now but the resources will be exporting electricity by DC links to Asia, exporting of hydrogen, exporting of synthetic hydrocarbons and exporting of refined mineral ores instead of unrefined mineral ores.

Thorsten Trupke: I know this won't happen overnight, obviously not, everyone knows that. There is a lot of technical challenges involved in this, but as I indicated yesterday the technical challenges can be turned into commercial opportunities. Solutions will have to be found and that will open up opportunities for small or large companies to exploit those.

Benjamin Hickey: That's very exciting. The science is there, the economic case is there, the technology is developing extremely rapidly. Do you think the trajectory is moving fast enough and what can we do to support that transformation?

Robert Bardos: Australia already has a huge competitive advantage in it's R&D space for Solar. So, [inaudible 00:16:55] at UNSW that was founded by Martin Green has got a huge amount of expertise in it which can be deployed to accelerate the industry in Australia if we chose to. It could be a very good case to fund R&D in this space, especially concentrating on the downstream aspects like the Solar modules installation, the large scale utility installation, the integration with the grid. All these things which haven't really been at the front of research agenda in let's say a decade ago and all of a sudden they are critical, how to make grid works with huge amounts of renewables in it? If we want to accelerate the deployment of renewables worldwide we could certainly start by doing it in Australia which would be one of the biggest renewable country in the world. So that's how I think we can do it, a relatively small amount of R&D support here will be leveraged enormously by the resulting industrial adoption.

Thorsten Trupke: It's fair to say that we have [inaudible 00:17:48] especially by the Australian Renewable Agency, Arena, but if you look at it on a bigger scale, the amount of funding we have received is good money for a small research group like us but on a bigger scale it is almost negligible. If you look at the funding that goes towards the other sectors and as you just said, in order to be able to deal with those technical challenges that are going to be on that path towards a very high percentage of renewables in the grid, more funding will be required and we certainly hope that government will look at it favorably and for example keep the specific funding like Arena going for many years to come.

Robert Bardos: Arena is particularity useful because it's funding a lot of different discipline that will go into this final mix. You've got people working on fundamental R&D, on root connection issues. All those things are required in order to increase the uptake of Solar [crosstalk 00:18:44]

Thorsten Trupke: And chips of course as Robert said a lot more work is going to be on the downstream side of things how the whole integration of renewables into the overall electricity market is gonna work that will have to be combined with a lot of research and planning into storage, battery storage, pumped hydro. These things are often mentioned by politicians, I remember my [inaudible 00:19:03] last year he was talking about snowy hydro 2.0 and I love that idea because pumped hydro is an amazing efficient way of storing energy and then generating electricity when it's needed. But to my mind it felt a little like, he mentioned this snowy hydro 2.0 a bit out of context, what is required is storage solutions like that but they have to be part of a overall bigger plan in terms of what is going to be the amount of solar, the amount of wind, where are these storage places required. There is research going on in this space, for example at the ANU and Ublec is doing a lot of work in this area but there is a lot more that needs to be done and funding is required for that.

Benjamin Hickey: Finally, how did it feel to win the Clunies Ross Award for Innovation?

Robert Bardos: It's fantastic to get that recognition it was a really great thing to receive. I very much enjoyed the night last night, there were many more people than I expected and it was good to see the federal minister there.

Thorsten Trupke: Yeah, as Robert said it's a great recognition. It is certainly a great motivation for us to keep on abiding and driving this technology forwards. Ceremony last night was very nice and it's always a very nice opportunity to network with a lot of people from different areas.

Robert Bardos: Yes, I had some quite unexpected conversation with people completely outside my area so that aspect of it was very interesting actually.

Benjamin Hickey: Fantastic, so thank you so much for chatting Thorsten and Robert.

Thorsten Trupke: Pleasure.

Robert Bardos: My pleasure.

Benjamin Hickey: Thank you.