Chancellor’s Lecture:

Nuclear Energy

Dr Ziggy Switkowski

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SWINBURNE UNIVERSITY OF TECHNOLOGY

Welcome

Dr Michael Thorne

Members of the Swinburne Community, welcome to tonight's Chancellor's Lecture. My name is Michael Thorne, and I work in the Chancellery here at Swinburne University of Technology. This evening, we commence by respectfully acknowledging the traditional owners, the people of the Kulin nation as custodians of this land. We also pay respect to all Aboriginal Community Elders, past and present, who have resided in this area and have been an integral part of the history of this region.

To introduce tonight's guest speaker, I welcome one of the key people behind the development and implementation of the Button car plan. I also welcome the former Chair and CEO of the Productivity Commission, a former head of the Victorian Public Service, a former Group Managing Director at Telstra, a key panel member of the Federal Government's Review of Higher Education, the person who cleaned up the problems at the City of Brimbank. I'm also going to invite the current Chair of the Port of Melbourne Corporation, a person reviewing public funding of schools for the Federal Government, a person reviewing the State's Child Protection System for the Victorian Government.

Friends, I know it sounds like I'm about to invite nine people up to the microphone; however, all of these contributions and many, many more besides are the work of just one person. He is, of course, Chancellor of Swinburne University of Technology, Mr Bill Scales, AO.

Introduction

Chancellor Mr Bill Scales, AO

Thank you, Michael, and can I say welcome to everybody that's here tonight. It's just terrific to see so many people in this wonderful building. It's also terrific to see so many alumni that we haven't seen before, and I hope that you understand that you are always welcome here, and I hope you also understand that this Lecture Series is as much about you as it is about the University. Because what we've tried to do with Swinburne over the last decade or so is try to provide you, the alumni of the

University, some ‘value-add’ for your role as one of us, as one of the Swinburne family. So, thank you for being here. We’re absolutely delighted that you are.

I would also like to welcome our new Vice-Chancellor, Professor Linda Kristjanson. Linda is going to talk to us a little later and give us a, I think, thank Ziggy, but Linda, welcome. It’s terrific that you’ve chosen us. You’ve done your homework on us I know, and we just think it’s fantastic that you’ve decided to be with us, and we think, hopefully, it will be at least a decade of great success, and I know it will be, with you at the head. So thank you very much for being here.

Can I also tell you a little bit about this building? We’re incredibly proud of this building, for a number of reasons. We’re proud of it, because, primarily, we funded it. We’re one of the few universities, I think, around the country, that takes great pride in the fact that we are always putting aside resources to do a range of things. We’re always putting aside resources to make sure that we’re rebuilding the university, and that’s going on almost as we speak. We’re rebuilding many of the classrooms, to make sure that they’re fit for not only our current students, but students for the future. We are also building new buildings. We are building buildings like this, and over the next 12 or 18 months, you are going to see one built also alongside of this, an advanced manufacturing centre that will be a showcase for what we think are the future of manufacturing ought to be – remembering, of course, that manufacturing still employs almost three times as many people as mining in this country.

So, there is a need and a reason why it is that an Institute of Science and Technology, like we are – a University of Science and Technology – is able to be able to build buildings like this, not only to advance scholarship, not only to give outstanding teaching and learning, but also to do research alongside of it. And this building, of course, is designed to do a number of things. It’s designed to do that. It’s designed to, in fact, create that synergy between teaching, learning, scholarship and research, and the building is designed to do that. And when we were thinking about the design, we were trying to make sure that it wasn’t just a building. It sent out a number of messages, messages just like that.

We also wanted to send out a message or so about the way in which we think about the environment. So, this building is made of recycled materials; it recaptures rainwater; it has lighting which adjusts in response to natural daylight levels; and it's got a building management system, which is linked through to the Bureau of Meteorology, and so it can actually predict and change depending on the weather. Now, why is that important? Because what we're trying to do all of the time is not only build buildings like this, but build those ideas into our research, into our teaching, into our learning, into our scholarship – because the way we think about the world, we think everybody who leaves Swinburne will have to face a world of constrained resources. So, we have to put that into our education. And we have to have a way by which we show people that we believe in it by what we do with our built environment. So what you're in now is a building, sure, but it's trying to send out another message – a message about what Swinburne is.

And there's another message as well, which is, you can see also by the glass walls. And that is: an institution like Swinburne has to be open to the world. So our research, for example – you see the research that's going on – as people are driving down Burwood Road, they will see that research. They will see the fact that research is not some esoteric thing that's done by people in some closeted room. Research is done by people in the real world for people in the real world. As so, again, we're sending out a message of what a building can do, to convey what Swinburne is really about. And of course, because we're talking about sustainability – and you would have had to have lived on Mars not to know that there's a debate going on right now about issues about sustainability, and how we as a community think about that in this current environment, we have Dr Ziggy Switkowski to talk to us tonight about one element of that debate, which is the nuclear energy debate. Ziggy is not only Chancellor of Swinburne University – not, no, I'm Chancellor of Swinburne University! – You're RMIT, aren't you? That's right. You're RMIT! Sorry about that. I meant to tell you, we need to talk about some sort of merger or something, you know! And we can work out who's who!

Ziggy is a former CEO of Telstra, Optus and Kodak Australia. He is also a former Chairman of the Australian Nuclear Science and Technology organisation. He is a Fellow of the Australian Academy of Technological Sciences and Engineering, and the Australian Institute of Company Directors. He is also a non-Executive Director of Suncorp, Tabcorp, Allsearch and Linus. And, of course, he is also Chairman of Opera Australia and, unfortunately, he is also an Essendon supporter. Sorry about that, Ziggy!

Ziggy is also well-known as an advocate – probably that's going too far – more somebody who wants a debate about nuclear energy, part of the current debate around science, technology and the environment. Community attitudes, of course, about nuclear energy have polarised in this country, as they are in many places around the world – and we've seen a recent example of that, of course, in Germany over the last couple of days, and Ziggy's presentation tonight will review all of these areas.

Can I ask you to join with me in welcoming Dr Ziggy Switkowski.

Dr Ziggy Switkowski

Chancellor, thank you very much for those gracious introductory comments, and for the invitation to address this group in this marvellous advanced technology centre, which is really just right out there at the leading edge.

Vice-Chancellor, distinguished guests, one and all, I am going to, tonight, try to update you on the topic of energy in general, but specifically nuclear power – particularly in the aftermath in the disaster that occurred in Fukushima in the early days of March, following the tsunami and earlier earthquake.

Let me set the context for my comments. A couple of years ago, the US National Academy of Engineering set out their views as to what were the 20th Century's greatest engineering achievements. So this is the last century. And they polled their members, who are informed technologists, and they produced a list. And the top ten in this audience probably won't surprise you.

Number one in the 20th Century was electrification. That's going to be important for my comments later on. Then the automobile; aeroplanes; water supply and distribution; electronics; radio and television; agricultural mechanisation; computers; telephony and then air-conditioning and refrigeration came in at number ten. A poll for the 20th century found the internet at number 13, a position obviously that would change if you took a survey about the early part of the 21st Century.

So, such a list reminds us of the breathtaking influence of science and engineering and commerce in defining the modern world, and also of the place that electricity now occupies in our lives. As a result, today, the demand for energy in all its forms – but particularly electricity – continues to grow. Notwithstanding your good intentions and mine to be more productive and more frugal, we are using more power all of the time. Typically growing at about 2% a year, which means that between now and 2050, we are going to have double the amount of generating capacity available to us in Australia and globally versus what we have today.

And look, that's understandable, because energy usage is synonymous with economic growth, with prosperity and with our standard of living. And in fact, there is a new universal relationship between GDP and energy usage. And that's used by our utilities as they plan for increased capacity.

Now, in Australia, we have little difficulty in meeting the demand for energy growth, but today's challenge – and it's sort of exemplified in the work that's gone into a design and building like this – today's challenge is to do this in the most environmentally-responsible way. And rules are therefore developing, where costs are being imposed upon carbon emissions and any use of fossil fuel. And, although climate change is a key driver of the current debate, there are other priorities, such as ensuring we have security of energy, diversity of supply and sustainability is also important.

Let me, early on, give you my take on the climate change debate. Because, in an audience like this, sophisticated and informed as you are, there will be a variety of views about the gravity of climate change and what people should do to mitigate it. So, let me tell you where I stand.

I believe the science of climate change is sound. Yes, the computer models that we use to forecast the future are very complicated and there's some uncertainty about the speed with which these changes will occur, but the changes will occur. I believe we are in an extended warming period. And therefore, the forecasts of climate change and the volatility that is predicted to occur, in my opinion, are directionally right. So, these forecasts anticipate more severe droughts; intense bushfires; hailstorms with hailstones the size of golf balls; floods; unreliable rainfalls; rising sea levels; species destruction; melting icebergs; receding glaciers. All of that, I believe, is ahead of us. We may have a difference of opinion about how fast it will happen, but happen it will. The main cause of that is the build-up of greenhouse gases in the upper atmosphere that is primarily carbon dioxide which is produced by the combustion of fossil fuel, by us and by our industries. The targets that countries have set to reduce their emissions by 50%, 60%, 80% in 2050 or thereabouts are scientifically-based and sound. This is a target, for example, that Australia has also adopted. Most countries that have these targets have good intentions. There are very few of us that know how to get from here to there while protecting our way of life and our economies.

Australia contributes a small proportion to the greenhouse gas emissions globally in proportion to our size of economy – just over 1%. 1.4% and falling. The major emitters are the major economies: the US, China, the European Union, Japan, India, Russia and Indonesia – that's about 80% of the world's emissions. How they go, goes the world's climate; we may well make a morally significant contribution to the debate, but not a practically significant one, because we're just too small. Climate change, in my view, is programmed in for the next 20 to 30 years. It's in the nature of the changes, it's a flywheel effect. What that means is, not that we have time to defer action, but any action we take today will make a measurable difference to trends next generation. Let's not do things today and expect that in the next five years, or worse still, in the next electoral cycle, we are going to see any change in the trend of climate, or weather for that matter. Steps do need to be taken today, in my view: investment in clean energy technology programs, conservation, adaption to climate change – again as exemplified in a design and building such as this – and yes, a sensible emissions trading scheme.

And again, just to get you on the page, if you accept that greenhouse gases are detrimental to our climate, then the scale, in terms of what's a high emitter and what's a low emitter, if we set a 0-100 scale, and 100 is brown coal, compressed dirt and twigs, which is basically what powers the Victorian economy. At about 70 is black coal. About 50 is gas. But they're all fossil fuels, they are all emitters. Then you drop down to about 10 – solar nuclear wind – and at about 2, you've got hydro-electric power. The fact that there's anything for hydroelectric power simply reflects that the measurement is taken over a whole of life, including all of construction costs, and dams take up a lot of concrete, and the production of concrete is greenhouse gas emissions intensive. So that's my view on climate change.

Let me talk a bit about electricity and particularly the generation of baseload electricity. Most demand for electricity is for a continuous supply around the clock. When you come into this theatre and you turn on the lights, you expect them to go on. When you drive home, you expect the traffic lights to be working. When you turn on your plasma TV, you expect it to go on, and you hope that the refrigerators continue to work in your absence. 80% of the electricity that we use is in this baseload form. If we are going to produce baseload electricity, our options are limited. We either do so by burning coal, by burning gas, by burning oil, all of which are fossil fuels, or we have an abundance of hydroelectrical power – which we do not – or we use nuclear power. That is the reasoning that has led so many countries around the world to introduce nuclear reactors and nuclear electricity.

If we have little tolerance for brown-outs and black-outs, and we require all of this baseload electricity, only these options are available to us. Down the line our intermittent renewable alternatives – wind and solar, pre-eminently – may overcome the intermittency problem and do it cost-effectively, but those solutions are not available to us today.

So, let me give you my take of what's happening around nuclear power, around the nuclear industry globally, and commentate from the perspective of the pre-Fukushima earthquake on March 11.

So, 14% of global electricity is currently being produced from 437 reactors in 31 countries. Two-thirds of the world's population gets some of their electricity from nuclear reactors, and most of the other one-third have aspired to introduce nuclear power. You cannot travel around the world without landing somewhere where the power is produced from nuclear reactors. The European Union gets 31% of their electricity from nuclear power. To me, one of the more telling statistics is that the neighbouring countries that were most affected by the fall-out from the one most serious accident in the history of the industry prior to Fukushima, which was Chernobyl in 1986. So this was a core fire exposed to the atmosphere, burned for ten days uncontrolled, radiation drifted into the upper atmosphere, pushed by the winds in the north-west direction and then settled on fields and animals, etc, for a long period of time.

The countries in the path of the fall-out – the Ukraine, Belarus, Poland, Russia, Finland – are all, or have been, increasing their nuclear networks, having made the decision that, on balance, the need for energy, the need to do it cleanly, and their confidence in the new technology of reactors, overcame their concerns in the aftermath of the '86 tragic, devastating, Chernobyl accident.

The United Kingdom, a beacon of climate change leadership and one to which Australians often refer, is committed to accelerate its nuclear build program, intending to replace its current fleet of 19 reactors, producing about 20% of their power, to double that in the 2030s. The US have said they can't meet their climate change and energy goals without more nuclear reactors. They have 104.

The countries with the most ambitious nuclear outlooks are, unsurprisingly, China, India, Brazil and Russia. The most dynamic developer of uranium resources, and now the market leader, is Kazakhstan. We may have most of the world's uranium, but so far, we've elected not to exploit it. The most active regions, in terms of introducing nuclear power, are the Middle East and North Africa, and Central Europe. Some of these countries present very interesting geo-political challenges, as well as opportunities for Australia.

Of the 57 reactors currently under construction, 24 are in China. They expect to add 63 by 2020. And in our part of the world, the following countries have a civilian nuclear energy program: China, Taiwan, Japan, South Korea, India and Pakistan. Vietnam has just ordered their first two reactors. Thailand, Cambodia and Indonesia were preparing to introduce nuclear power, although I expect that they will pause until the lessons of Fukushima are better understood.

If you rank economies by size of their economies – by GDP – Australia typically comes in at about number 15. The 14 countries above us, with the exception of Italy, are all nuclear-powered. If you go all the way down to find the next country that has no nuclear power in their system, you get to Denmark at number 28.

When you go to a G20 meeting, as our Prime Minister did in South Korea a couple of months ago, the G20 involves representatives from the 20 most significant economies. They're not nations, they're economies, representing 85% of the world's trade. Of all 20, only one has no local nuclear program. That's Australia. The Prime Minister would have been a very lonely person when the agenda moved to nuclear energy at that meeting.

So, let me reassure you, I will draw your attention to the issues associated with nuclear power, so that you get a perspective as to why it's positive, and why it might be negative. But if I were to summarise the advantages of nuclear power, I would say: The technology has been around a long time. It's well-established. The industry has been working since 1955. You aren't asking for technology breakthroughs when you buy a reactor and couple it into the grid. It is truly baseload – nuclear reactors are meant to run 24/7, 365 days a year. And, in fact, the most productive power stations around the world are nuclear power stations and they perform like coal and gas-fired power stations, in that they just plug into the grid, they do not create unreasonable demand on the transmission systems that often accompany wild surges in production from intermittent alternatives.

As I said, the greenhouse gas emissions, properly determined from nuclear power, are low, of the same scale as solar and wind. The costs of nuclear power are high. You spend four or five billion dollars on a power station that you might spend a third as much for a coal-fired power station. But the whole of life costs of nuclear power become very competitive and, in parts of the world which already have a modest carbon price, the cost of nuclear power turns out to be comparable to, if not better than fossil fuels.

In Australia, if we get a carbon price between $15 and $40 per tonne of carbon dioxide per year, and the press at the moment is speculating on some number between $20 and $30, then nuclear power will become the most competitive, safest and cleanest form of baseload electricity at that point, which I think will happen in the next several years.

The other interesting development with nuclear reactors is that most of the development effort has been at the big ends — big, very efficient, high up-time installations – there's some interesting work going on to produce small reactors, the sort of reactors with power, nuclear subs, with some variations. They're about a tenth of the size of a Hazelwood, for example, and as a result, much less costly. They require simpler cooling, sometimes no access to water. They're about the size of two shipping containers, can be built underground and present a less threatening fingerprint, footprint and profile to communities. I expect we will see those in the next decade, partnered with desalination plants, smelters and industrial towns.

Let me just segue a little bit, to give you a sense of what happened in Japan, and then I'll come back and perhaps summarise some of the arguments against nuclear power.

So, Japan had 54 reactors producing 30% of that nation's electricity; reactors built in the '60s and '70s by GE and Toshiba, high quality vendors. On March 11, a magnitude 9.0 earthquake happened off the coast of Fukushima, about 130km, in the ocean, followed an hour later by a tsunami, measured at about 14 metres, in terms of pulse height. The shaking was severe: two to three minutes, vertical sheer, sea floor was 18 metres. And Christchurch, which was the next most costly earthquake in the last 12 months, the vertical sheer was about 1 metre. So, the earthquake was at 2:46pm, the tsunami arrived at 3:40, at 7:03 a nuclear emergency was declared. All reactors had shut down, but the tsunami had flooded the precinct of the reactor, knocked out back-up power, knocked out batteries, knocked out electricity in the prefecture. An evacuation order was issued at 9:23pm that extended to 3km. At 5:44am the following morning went to 10km, and at 6:25pm the following day, it was extended to 20km, where it is today, and 100,000 people were displaced.

Eleven reactors were operating in the region when the tsunami hit. All shut down safely, but the six at Fukushima then lost power and lost coolant, and with reactors, you've got to keep them cool, even when they are not working. As a result, cores overheated, and as the analysis continues today, it is clear that cores melted in the three operating reactors. And I've got to tell you, if you've got a core meltdown, you're up at 2500°C. The containment vessel, which is a stainless steel – you think of it as kind of a ball of three or four or five metres in diameter – stainless steel, 27 metres thick, would have been glowing red-hot at the point where, inside, the fuel cells were melting in the absence of cooling. Radiation escaped, primarily not from the core, but from other areas, particularly the spent fuel tank, but – BUT – there have been no fatalities at Fukushima associated with the reactors.

So, in 25,000 casualties, dead or missing in Japan, three at the reactor site were people who died in the tsunami, but not from the reactor. There have been no casualties. There has been elevated exposure to perhaps 30 people, but not elevated to the point where it's expected to have enduring health effects. And there has definitely been exposure of the wider community to high levels of radiation which are, however, unlikely to lead to any measurable effects on their health – although there must be some effect over a large enough population.

The international authorities have rated the Fukushima accident on a 1-7 scale as a 7, the next worse accident after Chernobyl. There are a number of radioisotopes that were released. Most have decayed away, but not all. Of the 47 prefectures that make up Japan, one is still being monitored for the effect of fall-out on food and in the ocean, and there are, curiously, certain foods that concentrate some of this radiation. So shiitake mushrooms are in that category; berries; any of the leafy vegetables – lettuce, cabbage, etc; bamboo shoots. It will be months before the site is controlled; the authorities think sometime early next year and it'll be only at that point where the 100,000 people or so that are currently displaced might be allowed back into their homes.

Drinking water has been cleared now for the better part of a month. That's not an issue anywhere in Japan, and frankly, neither is food, nor is any level of radiation above background radiation, except in the immediate vicinity of the Fukushima plant.

The cost of this has not been estimated, but it probably isn't known. But, to replace all of the reactors at the Fukushima site (which is six), to decontaminate the site, to decommission the reactors, to compensate people, it's probably about – and this is MY number, I've never seen this number published anywhere else – about $50 billion. Interestingly, for reference, when the deepwater Horizon oil spill occurred 13 months ago with 11 fatalities, the aggregate cost to the industry and to the economy is also expected to be about $50 billion.

Internationally, countries that were about to re-enter nuclear build – Italy, Poland and Thailand – have paused. They will await the outcome of the review in Fukushima. More recently, Germany has announced that they will phase out of nuclear power altogether. The German commitment to nuclear has always been equivocal and hostage to political changes. Now they seem to have taken a fairly definitive position, and where 23% of their electricity is produced by 17 reactors, within 10 years, they expect to phase out all nuclear power and substitute with—? And that question remains to be answered.

Japan, too, which had a plan to go from 30% to 50% electricity by 2030 with nuclear, is pausing, understandably. They have an issue with filling the lost capacity today. They have shut down a number of reactors, ahead of rebuilding higher walls against future tsunamis. Of the 54 reactors, 11 were shut down at the point of the earthquake and tsunami, but others have been shut down as they have been reviewed, with a view to strengthening their defences. Only 19 of the 54 reactors in Japan are currently working.

The US and UK and EU have all undertaken inspectors of their nuclear fleets and certified them as 'fine'. But as I say, most countries about to start nuclear builds will be hesitating, quite reasonably, quite properly. However, the countries where the nuclear programs were most aggressive – China, India, Middle Europe – where they need the energy to power their economy (in some cases to provide any form of electricity to its citizens) that growth will continue without pause, as best as I can tell.

Okay. Let me give you the concerns about nuclear power, because as I go around and talk to audiences and try to respond to questions, there is a repeating pattern of concern that, particularly Australians, who have no history with a nuclear industry, have. And there is a kind of a dozen or so questions that may well be on your minds as well. Usually the first question has been – this is, again, a pre-Fukushima experience – is about the radioactive by-products. Long-lived radioactive waste. It's toxic, hard to handle, it lives for a very long period of time and, if you search around the world for how countries have managed this, you can't find any country having built a national repository to store the spent fuel safely for the hundreds of years that will be required, if not the thousands of years. So, the industry struggles to persuade people that there is a safe solution for spent fuel, even though, technically, in an engineering sense, it seems straightforward. From a social sense, it's usually been a struggle to get people to accept that, if you've got a nuclear reactor system, you also need to have a repository for the spent fuel.

Other reservations include the fact that nuclear power is costly. It is, in a capital sense. It's not in an appropriately-calculated operational sense, including the cost of capital. But, nevertheless, if you struggle to find the $4- or $5 billion per gigawatt of electricity generation, you can be put off by those costs, and some people have been.

In Australia, because we have no enabling legislation to permit a nuclear industry, even if we all were to agree, including our political leaders, to go with a nuclear industry today, it would probably be ten years at the earliest – perhaps more like 15 – before we would have our first nuclear reactor. So, if your planning horizon is 2020 – and for many people, 2020 is their horizon, nuclear will not be part of your thinking, understandably. My own view is that issues of climate change and energy strategy should be referenced to 2050, at which point I expect that the world will have a lot more nuclear power than it has today.

Some people – a lot of people – are concerned about where you would put these reactors. It's an easy political scare campaign; it has been used by politicians in the past. If we were to supply all of our electricity with nuclear reactors – and this is not a plausible scenario, but for purposes of discussion, let's say we have 50 reactors, which would be all that would be required to supply all of Australia – they're usually built three or four to a site. So you need, perhaps, 15 sites, mainly around the Eastern seaboard.

When people overseas are told that we, in Australia, will struggle to find a location for nuclear reactors, they think this is a unique form of Australian humour! For example, in the United Kingdom, whose surface area is about the same size as Victoria, they squeeze 60 million people in and 19 reactors, and until now, in Japan, which is a difficult geology – very difficult, right, tectonically unstable, etc, in the path of typhoons, tsunamis – 127 million people live in islands that are one and a half times the surface area of Australia, and they have 54 reactors.

Anyway, the location of reactors is an issue for many. The risk of catastrophic accidents usually came up – and clearly will come up every time now. Until Fukushima, Chernobyl was the reference point. Now it's Chernobyl and Fukushima. We need to have answers as to whether the circumstances in Japan were so unique and specific to Japan, that they need not be considered as probably elsewhere. But that is an open question.

Other issues around proliferation and terrorism come up, although they tend not to be up there near the top. Access to water for cooling, etc, are other issues. Let me just give you – before I pause here and invite your questions – let me give you some other statistics about how other countries have decided to locate their nuclear reactors.

France is the benchmark case. The surface area of France is somewhere between Victoria and New South Wales. Into that space, they squeeze 58 million French people and they have 59 reactors, producing nearly 80% of their electricity. Their industry has been working successfully for the better part of 40 years, and when they talk to us in Australia, they say, "We have a country with three times your population (nearly), three times your GDP (nearly), but our greenhouse gas emissions are lower." Why? Substantially because of their clean energy platform, which in this case is nuclear power.

South Korea has a surface area that's a little under half of Victoria's – 48 million people, 20 reactors.

Italy, which had nuclear power, shut down the reactors after Chernobyl, put legislation in place two years ago to re-start their program, started the process and have – this week, or this month – paused in the aftermath of Fukushima. But they have an area about the size of Victoria, and were planning to put 10 reactors in by 2030.

So, you can see why countries who look at Australia and our continental size and our population spread find it hard to accept that we would find it difficult to agree on locations for nuclear power stations or a national repository. What countries are doing that are introducing power for the first time in selecting locations is the following:

The Government appoints a panel of eminent people such as are gathered here tonight – maybe ten of you. You are given a set of criteria for a location. It needs to be close to the electricity grid; it needs to have access to water – sea water is fine; it needs to have access to some sort of workforce; and it need not be close to a major city, but it needs to have access to a marketplace. And these people are given three to six months and they come back with a list of 10 preferred sites, ordered, and then that is given to the Government. The Government then overlays their political considerations, as Governments do, and you've got your locations. That's what we would do, were we to go in that direction. Usually what you'd find is that the early reactors are co-located with coal-fired power stations, because those power stations already satisfy those criteria.

I've talked to you a little bit about the situation with respect to waste. What happens with spent fuel is that the enriched uranium in the core of a reactor is removed after three years, after which the enriched uranium has largely been (but not completely) consumed. The removed spent fuel rods are very, very hazardous. They're hot thermally, and they're hot in a radiological sense. They are put carefully into a very large pool of water, about the size of an Olympic swimming pool, but perhaps ten metres deep, where they will sit for a number of years. During that time, they will cool thermally, and they will cool in a radioactive sense. After that, they are taken out, they are relatively easy to handle, usually encased in a concrete layer, and queued up within the boundaries of the reactor, usually in an open field, until the end of the reactor life, which is 50 or 60 years, after which they tend to be – the intention is to truck them or railroad them to a central depository, which is an engineered hold in the ground, 500 metres deep, which by mining standards is not a deep hole, in a place that is geologically stable without any active water flowing in the immediate vicinity, which largely describes three-quarters of Australia.

As I say, in the next ten years, we will expect to see these repositories in countries that are actively pursuing their nuclear program. Were Australia to go nuclear today, and if we take the policy decision and we have our first reactors in the 2020s, we would need to have a national repository, which would be a single site with light security in the 2070s, at which point there would be dozens of these repositories globally, and we would be able to select a best-in-class design and implement it locally. So, a national repository at this stage doesn't seem to be a big hurdle.

Having said that, as a nation, we are struggling to put in place a national repository for low-level nuclear waste. What's low-level nuclear waste? The by-products of medical treatments, nuclear medicine, radioactive sources used by universities and by industry – and usually this low-level waste is if I'm doing some sort of nuclear medicine treatment and I'm using gloves. I'll take the gloves off and that constitutes low-level waste. Often it's overalls and gloves and masks and that sort of thing.

As a nation, we have all of these spent sources distributed everywhere and uncontrolled – in hospitals, in universities, in buildings. Why? Because we cannot get our act together. And whenever the Federal Government seems to be close to agreeing on a site where the repository would be a small dent in the ground, lined with a bit of plastic and a little fence around it, we can't agree, because it is so easy to alarm people about low-level radiation, even though, many of you know, your smoke detectors are, in the main, radioactive sources.

Right, so let me conclude here and suggest some sort of obvious – to me, anyway – next steps. The current national debate about greenhouse gases, a carbon tax and an emissions trading scheme is a first step – an important step, but the agenda is larger than that. The main game, in my view, is to design an evolutionary path along which the Australian economy progressively reduces its dependence on fossil fuels, while enhancing its productivity and competitiveness. To me, assembling a range of novel, niche energy technologies – and that I extend to wave power, tidal power, biomass, algor mechanisms, etc – all of that is interesting and intellectually fascinating but, frankly, is neither ready nor is likely to be efficient enough to provide us with an industrial grade energy system such as we enjoy today. Our economy and our society has benefited, for generations, by having access to low-cost fossil fuels and a very, very efficient energy infrastructure, which we are intending to move away from for a variety of reasons – which I do not challenge; I just make that observation.

In my view, nuclear power should be in the mix. In fact, we could easily make it the most important component of our energy portfolio by the middle of the century. We won't be alone in this position. France is, as I said, already at 80% of its nuclear energy with reactors. A lot of countries are in the 20-30% range. I do accept that until the Fukushima analysis is completed – and assuming that there aren't any nasty surprises in the analysis – that some of the ambitious expectations for nuclear power globally will be pared back.

In order to make any progress – any progress – we must have bipartisan agreement – political agreement – on the legitimacy of nuclear power in our planning. We are not even close to achieving that. The Labor party in Government rejects nuclear power at this stage; the Greens are ideologically opposed and the Coalition Government refuses to put its head above the parapet on the subject.

So, I think it was always going to take some time to get to that point. The recent developments in Japan suggest it might take longer than I thought, but the time will come – not in this electoral cycle, maybe the next – when we confront, realistically, the dramatic challenge of the sort of move we have to make away from fossil fuels – given that people are, in the main, determined to do that, and we look around and say, "And what will we do to make that move while preserving our industry and economy and quality of life?" and discover we have very, very few options. And also, maybe rebuild our confidence that we are good enough and smart enough to run a nuclear network safely and cost-effectively.

In order to continue on, we have to authorise and resource our nuclear regulators. We have regulators, nuclear regulators, that oversee the Lucas Heights reactor that I was associated with until recently, as well as industries and the health system's use of radiation, but they need to be resourced up and to design appropriate protocols and regimes for a larger nuclear industry. We would have to re-establish tertiary level education and training capabilities, such that an industry would demand. When I was doing my graduate work in the '60s and '70s, and if you were an ambitious, experimental scientist, nuclear physics was where you headed. But shortly thereafter, with the loss of interest in the nuclear industry post-Chernobyl, and decisions by Australian governments not to progress with nuclear power, not to expand our uranium industry, most of the careers dried up and most universities wound back on their undergraduate training. We'd have to re-establish that – I think we can do that. There seems to be a readiness to adapt curriculums accordingly. We would still need a national policy that was consistent about that. I think we should start the determination of prospective sites for our first reactors. I think we could easily have our first reactor up and running in the early 2020s, and then you can build at a rate – at any rate, really – once you're confident of your choice. Ten reactors in 2030 would produce a quarter of our electricity, and as I said, if you had 50 by 2050, that would be just about everything.

Let me also remind you, there is a sense of purpose and inevitability that we are going to progressively move to electrification of our transport system. Initially, hybrid cars, and then cars that run off rechargeable batteries, or maybe a kind of a hydrogen fuel economy but the hydrogen has to produce. What does that mean? The demand for baseload power will increase even more, even more. And we will be searching around for how to do that. In other words, this is a coupled system.

You can't make these decisions on your own. You have to understand – for example, roughly, it's hard to know, but roughly 10% of global energy powers the internet. All of the servers, all of the storage devices, all of the appliances, which are growing quickly. We are inventive when it comes to coming up with schemes and devices that assume electricity is always going to be there and it's going to be affordable. I'd like to plan to provide for that.

A number of people – some may be in this room – believe that that is the wrong direction, that we need to be more frugal with our use of energy. We need to de-tune our lifestyles. Instead of you all rushing out to buy your second and third and fourth plasma TVs, you should be happy not only with one, but perhaps even with carefully scheduling access to that one. I hope we never get to that point, but I acknowledge, before any of you come at me later on, that some of you take a different view.

Okay. So, let me conclude by saying, well, I think, where the role for Government is most important in this is the following:

We do need to have clarity about the nation's energy strategy and goals. That clarity should be helped by the publication of an energy white paper. This is a formal, high quality process mostly. In this case, it has been much interrupted, much delayed, and poorly set up – perhaps with improvements on their way. We, as a nation, don't have leaders yet who can say, "In 20 or 30 or 40 years, this is what we hope the economy looks like when it comes to energy provision." I agree it's difficult, and I agree that the environment of public debate and media scrutiny means that you'll get belted no matter what you say. But until we are clear where we are heading, with sufficient conviction that industry can line up behind that, not much is going to happen. And in fact, for all of the noise and debate that's going on at the moment, not much is happening. We do need to get bipartisan support, initially, for the energy strategy, eventually, I hope, from nuclear power. I acknowledge we don't have that. We do need, as I said earlier, to establish a world-class nuclear regulatory authority to oversee the industry, to control it, to reassure people that it is operating safely all of the time under a range of theoretically hazardous scenarios. And then we have to invest in skill-building and education.

Ladies and gentlemen, thank you for your courteous attention, and I'd welcome any questions and challenges and alternative views that Michael might permit. Thank you very much.

Question: **Yes, hello Ziggy. I'm very interested in nuclear as a potential option to combat climate change, because I think that is an issue that we really have to get on top of as quickly as possible. I'm interested that you dismissed concentrated solar plants straight off there. It seems to me that, although they're more expensive now, they've just become feasible. Their technology, their cost, economically, is coming down. Nuclear has been around for 50 years and it's going up. How likely is it, do you think, that nuclear will actually be more cost-competitive than concentrated baseload solar in 10 years, 20 years, given that either of these plants will be around for 60 years?**

Look, firstly, I'm generally in agreement with your sentiment, and I hope I haven't dismissed concentrated solar thermal, which are these large arrays of mirrors that focus the sun, often on a column of molten salts which circulate and then generate electricity in a conventional way. There are a couple of very large concentrated solar plants being installed as we speak, in Spain, in California. I think, 100 years down the line, some form of solar technology is going to be a very large part of the energy mix and some form of nuclear technology – it may be fusion, but it'll be nuclear. So I don't dismiss solar out of hand, but today— One of the countries that has put the most amount of effort into solar energy in a variety of ways is Germany. They're going to put more, now that they're going to decommission the nuclear power stations. They have a huge feed in tariff to incent consumers to put in domestic solar systems. Their contribution to the total energy budget in Germany: 1%. So I accept that we know what the economics of nuclear are, because we've been living with nuclear power for 50 years. We don't know what the economics of solar thermal are likely to be. We don't know about how that technology will scale and perform, but I am entirely with you – I hope it succeeds beyond our expectations. I actually think it's one area that we have underdone in Australia in terms of investment in, and I think it will loom large, but I think it's decades, I don't think it's years. That's my view.

Question: With regard to reactors currently being built, is there much variation in design? Or to put it another way, is there any attempt at standardisation world-wide?

That is such a key question. In the US, there are 104 reactors. There must be 40 different designs. And they need 40 different kinds of fuel assemblies, etc. I mean, it's just— You wouldn't do that.

Now what's happening is – and this has been a move for the last five years – the vendors have been encouraged by global regulators and governments to come up with a small number – maybe five – conventional or standard designs. And that will mean improvements in manufacturability and improvements in the ability of regulators to authorise these reactors. But the biggest change that is happening at the moment is that China has entered the market. Until now, the vendors of nuclear technology have been Western companies – Areva in France, Toshiba (if you call that Western), Westinghouse, GE, Hitachi, etc. China, by virtue of the fact that they're the biggest customers for nuclear technology, has insisted that intellectual property be transferred to them in the manufacturability of these reactors, and they are improving upon Western designs, but they are doing it in a single-minded fashion, focusing upon driving down costs and compressing manufacturing time. So they're on a path to ensure that, from go to whoa, they can build a reactor, instead of in five or six years, in under three. And they have made breathtaking progress in the last five years. And as I said earlier, nearly half of the world's current reactors that are under construction are Chinese reactors.

I think – and this is a provocative view for many – that when Australia is ready to order their first reactors in the next few years, we'll be buying Chinese reactors. They'll be the lowest-priced, and they'll be the most reliable.

Question: [inaudible]

I'll rephrase the question. Ramesh has asked why do fuel rods remain hot? And why does the core of a reactor remain hot even when it's shut down? And that's because there is an intense amount of residual radioactivity that then begins to decay and you're in an enclosed environment – or even if you're not, if you're in a pond – that heat just builds and builds and builds. And unless you're circulating water, certainly in an enclosed environment, you can get temperatures as elevated as thousands of degrees.

Let me give you the example: geothermal power, which I haven't mentioned, but in which a lot of people have high hopes. So, you hot rock geothermals, you drill a well, a hole, 5 km down, you find a space which has been heated up by radio-active decay in a structure which is kind of insulated so that the heat hasn't got a chance to get away. And usually the heat will be 500 or 600° And it's nuclear radiation from the primordial uranium and thorium that makes up the crust of the earth. In fact, wherever you turn, nuclear energy is powering our lives. Wind energy is driven by the sun; solar energy is driven by the sun; geothermal energy is driven by the sun; tidal energy is probably lunar – I won't claim that for nuclear. But most other things are nuclear. The problem that Fukushima has dramatised is that, even if you have multiple layers of backups for power, if you lose all those layers defencing [sic] in force, which they did, and you lose cooling, you are in desperate trouble. And you would have seen these television pictures of helicopters water-bombing the reactors, (which probably made for good television, but was probably pointless); more importantly, the water cannon directed at the core and into the spent fuel – all in a desperate attempt, ultimately partially successful, to keep these fuel rods or reactor cores sufficiently cool that they don't then in some way fracture and release radiation, which was always a concern. And as I said, it was only partially successful, because a lot of the radiation that was released in an uncontrolled way came from the spent fuel pond which lost its cooling water and permitted the spent fuel rods to overheat, react with the atmosphere, and release radioactive gases.

Question: I'm trying to gain a perspective here. You mentioned about cycles. What do you think is an energy cycle in nuclear, noting the fact that we started with our fossil cycle at the dawn of the industrial revolution, in the context that Chancellor Merkel has just announced that Germany is now going to phase out nuclear in the very near term?

I'm not sure that Germany's decision is all that meaningful to the way countries are going to look at their nuclear energy strategy. Germany has always had this fragile level of support for nuclear power, and it has reversed its position a couple of times as elections have changed. So, the fact that at the moment the Chancellor has decided to put forward a plan to reverse out of nuclear is neither here nor there for the rest of the world, I think.

I think there is a positive to that, and that is, an economy as powerful and as inventive as Germany's is, if they throw a lot of resources behind renewable technologies, which I think they are preparing to do, may lead to advances sufficiently quickly that the rest of us can learn from that. So, that's Germany.

But in terms of your cycles, it is true, you can think of any— I mean, we went through a long period of mankind's history where the primary source of energy was burning wood and wood products or manure and that sort of thing. Then the industrial revolution occurred on the back of coal, and then oil became significant at the early part of the 20th Century, and they've kind of cycled through. By the end of the century, we were very dependent upon oil, coal, gas and nuclear, and it would be a smarter person than me to kind of anticipate what might be the case 100 years from now.

As I said as I read the list out at the beginning, if you had asked people in 1910 what was their biggest environmental challenge, it was the management of the accumulating horse manure in the streets, because that was the primary form of transport. Could they have envisaged a community dependent upon oil? No. So, I can't think 100 years from now, but if I had to speculate, I do believe that most of our energy in 100 years time will not come from burning things, it will not come from spinning turbines on windmills – that will strike people as rather primitive. It will come from solar energy and it will come from some generation of nuclear power. It may be nuclear fusion, although nuclear fusion is, itself, very, very technically difficult. And I think that's the phase we're going to move into. But in the back half of the century, not in the front half.

Question: I would just like to know your thoughts on thorium as a fuel source instead of uranium?

That, too, is a popular question about whether, instead of using uranium as your primary fuel, you can use thorium. There are advantages in using thorium. It's an adjacent element in the periodic table. The burning of thorium does not produce plutonium as uranium does, so you don't get involved in producing a product that could ultimately be diverted for nuclear weapons. It has the advantage of producing fewer (slightly fewer) radioactive by-products and it is vastly abundant in black sands, etc. So they're all ticks.

The difficulty is, it's a difficult fuel cycle to get started. Thorium looks a bit like uranium-238, the non-fissile isotope of uranium. It's "fertile but not fissile" is the way the industry describes it. There's been a lot of work done on thorium, particularly in India. India's interest in thorium largely was motivated by the fact that they were not allowed access to the world's uranium because they were not signatories to the Non-Proliferation Treaty, and still aren't, but a couple of years ago the world, led by the US and Australia, configured a solution that permitted India back into the nuclear club, even though they didn't sign up to the Non-Proliferation Treaty. My sense is the interest of India in thorium will fall away as a result, because uranium is so much easier to work with.

However, if you look far enough ahead, might thorium prove to be a better, cleaner, safer alternative to uranium, yes, I think we'll creep up on it, we'll begin to add thorium into the mix progressively. And again, I think of second half of the century technologies – I think that'll be one of them.

Question: I'm interested in the waste from recycling and, by your own admission, you know, 100 years is a long way to predict for you. Given the susceptibility of the sort of James Hardie limit of commercial responsibility for waste, how do you think we are going to go accounting for the economics of nuclear waste, given their long life-cycle?

Yeah, look, it's a fair point. But of course, the industry is 55 years old, and nuclear-powered countries have wrestled with this issue. And so, what you find, if you were in France or the US – I presume other countries as well – when you get your electricity bill every quarter or every month, it says so many cents per kilowatt hour for your usage – 20 cents or thereabouts; so many cents per kilowatt hour for management of spent fuel – that's actually decimal points of a cent; and so many decimal points of a cent for decommissioning of the reactor. And those funds are put into a future fund structure, invested and held for when they have to be applied to the building of a repository or the transport of spent fuel, or the decommissioning process which, in most cases, will take decades. So, that model is well-established.

But let me extend my answer to another part of the question here, and that is, there will come a time in the next 20 or 30 years where we won't use uranium just in one pass. It'll be recycled. And we will learn to burn what is currently considered to be spent fuel. And there are ways to do that with breeded technologies which are very promising.

Also, a number of countries have taken different approaches to the storage of spent, or nuclear by-products. Some say, "Well, this is a waste product. We will store it in a well, and we will permanently seal it." So you go 500 metres down, you have an engineered cavity, you fill it up with spent fuel rods, and then you fill the top 200 metres with concrete. It's done, dusted and it will never, ever, ever, ever move. And I can say that because geologists – of whom there might be some in the audience – can tell you whether a particular rock in a particularly stable zone has been stable in that spot for a million years. Some countries have taken that view. Others have said, "No, no, no. You don't understand. Spent fuel is rich with complex radioisotopes where next generations may find a unique application." So they are building repositories where you can remove the spent fuel and use it.

My final point on spent fuel is, we may well be torturing ourselves in debating the merits of all of this. Let me assure you, 100 years from now, this is all going to seem pretty trivial stuff – very trivial stuff. I view my obligation is to ensure that between now and 100 years, we don't screw things up, but we leave it in such a way that the generations of the 22nd Century can turn up and say, "This is our equivalent of your horse manure problem. What problem?"

Question: **Dr Switkowski, I wonder, do you see there's a moral dimension in the current nuclear debate, in the fact that Australia has some of**

the biggest uranium deposits and we supply the rest of the world with them? Does that enter into your equations?

Well, if I were to interpret your question as saying, "Is it morally correct that we export uranium and then have no continuing obligation for it?" which is the way it works today, it's quite interesting, that point. The industry practice is, you do not have whole of life cycle responsibility for any of these fuels. And the uranium industry would also say that we export sufficient uranium a year to offset all of our emissions as a nation. So, in a way, you could kind of – I don't mount that argument, but the numbers cutely match. But let me give you the details.

Every country that I know of that has a nuclear program also has laws on its books that say, "If we produce the waste in our reactors, it is our responsibility". We may not export it. They also have a law that says, "And we will not import anybody else's waste." So although there have been creative businesspeople out there saying there's a market out there for the world's waste, there isn't. At least not in the established countries, as I understand it. So, for whatever reason, the world has sort of agreed on a particular operating model. So, if I import enriched uranium and I use it, then I'm responsible for the management of it thereafter. And I accept that. I don't have a morally difficult position in understanding and accepting that.

DR MICHAEL THORNE

Thank you everybody for your questions. They've been terrific. It seems to me that this evening, there have been three Chancellors looking over the proceedings – Chancellor Switkowski from RMIT, Chancellor Merkel from Germany, and Chancellor Scales from Swinburne! I'd like to invite Bill Scales to come back up and take the microphone.

CHANCELLOR MR BILL SCALES, AO

What an outstanding performance, really. You can see why I regard him as one of my very best friends, and you can imagine what the discussions are like when we actually get ourselves together. It's a pleasure to be his friend.

I have also the great pleasure now, as I said to you earlier, I wanted to just introduce to you Professor Linda Kristjanson, but I want to give you just a little bit of background to this.

When Ian decided to leave us – and that was a shock, as you as alumni of Swinburne would know. It wasn't our choice that Ian left us, and we would have preferred at that particular time that he didn't, but he did, and of course, he could not say no to going to the ANU, and we fully understood that. So, we set about doing what you would expect us to do as a Council, and that is, find the very best candidate that we could. I'll give you a bit of a sense of what went on.

We produced an information kit to find our new Vice-Chancellor. There were 80 information kits distributed to people who were interested in the job of Vice-Chancellor here at Swinburne. We developed a long, long list of around 20 acceptable candidates. We established a long list of about 9 candidates, all of who would have been acceptable to have been Vice-Chancellor of this august institution. We established a short-list of five. In that short-list of five, without going into too much detail, we had every one of them that would have been acceptable as Vice-Chancellor of this institution. We had some that you could regard, somewhat euphemistically, as outstanding candidates who would have been a safe pair of hands. We had candidates that had enormous potential. We had candidates who came from left field, who had no experience at a university, but were outstanding researchers and had managed a large research institution.

The outstanding candidate was Professor Linda Kristjanson. Please welcome her to the podium.

PROFESSOR LINDA KRISTJANSON

Thank you very much, Chancellor, for that very gracious and very generous welcome. Dr Ziggy Switkowski, our most valued alumni, ladies and gentlemen and friends, I would like to thank you so much for being here tonight for this really remarkable presentation that we've received, so thank you so much.

I would also like to say thank you to the Swinburne community for welcoming me. It has been an extremely warm beginning and my husband Joe and I look forward to deepening our friendships as we make our home here in Victoria.

On behalf of Swinburne University of Technology, and everyone here tonight, it is my privilege to extend a very hearty vote of thanks to Dr Switkowski for taking time to share his vast knowledge and experience with us on the topic of nuclear energy, and for allowing us to benefit and learn from the open discussion.

Universities are, by their very nature, places where individuals can come together to seek understanding, examine evidence, and freely discuss and debate any subject, whether it be thought-provoking, obscure or controversial. It is my strong belief that universities have a critical role to play in a civil society, whereby we offer a safe environment that provides and encourages exploration of ideas, devoid of ramifications or consequences.

It is appropriate that the topic of energy is the subject for the first public event in our new Advanced Technology Centre. We have invested $250 million dollars in infrastructure and research, including this $140 million state-of-the-art Advanced Technology Centre, the first building in Australia to be awarded a five-star green rating by the Green Building Council of Australia.

It is evident that Swinburne embraces the need for practical solutions to a 21^{st} Century and questions about energy and innovation policy form key components of our teaching and research programs. Your presentation tonight, Ziggy, is therefore consistent with our commitment to enquiry and our responsibility to address current and relevant issues.

Dr Switkowski mentioned, in his talk, the importance of re-establishing the tertiary level education and training capabilities that Australia will demand. He also mentioned the importance of skill-building and the need to forge international collaborations. Swinburne is playing a prominent role in engineering, science and social policy education and research. For example, we are home to Australia's first accredited course in carbon accounting and, with the support of our alumni and industry partners, we are undertaking innovative research that will contribute to sustainable energy solutions, leadership development, and provide trustworthy evidence to inform sound policy formulations. Dr Switkowski underscored the importance of comprehensive education and training within a framework of international collaboration, and we appreciate and receive these messages.

And so, to Ziggy, once again, I would like to sincerely thank you for delivering the first Swinburne's Chancellor's Lecture for 2011. It has been our most heavily attended lecture to date, with nearly 500 people registering. It has been our great pleasure to listen to you and discuss your views with you, and we have a small gift that we'd like to offer you as a token of our appreciation.

END OF TRANSCRIPT