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Nobel Conference 48

Well, I just said to Jim, that was probably the best introduction I've ever had. Although I feel a little naked now. I do have an amazing mother and father because they did let me and Barry Bruce, Barbara Block would know Barry, have this job at the Oceanarium and she trusted that there was somebody supervising us, but there wasn't. [laughs][laughter]

But I'm here today to say that, and Barry's now a white shark researcher in Tasmania, that we got through those, it was good money, too. Anyway, look, I wanted to start by saying really three things. The first is, in the last 2 days here in Minnesota, that's how you say it, right? [laughter] Yeah. That's one thing I've learned, it's a great state, by the way, is just what a wonderful college, wonderful students, a wonderful president, and what a wonderful conference we have here and what an amazing audience. We dream of audiences like this at the University of Queensland.

So it's really amazing that this has been going on for, well, 48 years in terms of the conference but that Adolphus, Gustavus Adolphus College is celebrating 150 years. I mean, that is incredible. [applauds] Amazing. And it really humbles us and we just celebrated our centenary and I thought that was pretty good but we're a bit humbled now.

The next thing I want to say is that, is to say thank you to all the people that have actually hosted us and particularly President Ohle, Chuck, Jim, Tara, Matt, and Jake and the many other people that have really made me feel very welcome here. And then the third thing I want to say is who sandwiched me between two of the most cleverest environmental philosophers and writers, after all the other scientists had their, you know, it's tricky.

So I'm going to show how limited I am by comparison. Because you have before, me, and then after. But I'll, I'll do my best. I think some of the messages I'm going to talk about today, about that great ecosystem, will be almost like a worked example of where science is going and where we need to go, and hopefully there are hooks on this which I think we can build in the messages that we've heard so far from Kathleen and I'm pretty sure we're going to hear from Carl.

So let me just get to the first image. I want to introduce you to the Great Barrier Reef. And, by the way, those images behind, I'm an amateur videographer and very amateur but those fish were very much outside my lab on Heron Island and that's a great privilege because I actually do live on part of the Great Barrier Reef that's in extremely good shape right now.

But let me just show you some of those organisms that live on coral reefs. And so coral reefs are this amazing thing that you see from space and it is, I think, one of the few signs of life on our planet. So when you look at that ecosystem, and I want to stop it right there if I can and, just to look at the number of species in that photograph. Does anyone know how many species live on a coral reef? I hear a million. Well, you know what the answer is? We don't know.

And that's not because I have been a poor scholar. That's happened as well. But the rate of discovery of new species on the Great Barrier Reef is such that it's probably, or coral reefs like the Great Barrier Reef, is somewhere between one and nine million species, a large number of which are unknown to science. And one of the expeditions I'll talk about later in this talk, 6 days with robots going down to the euphotic zone on the Great Barrier Reef, we discovered a new species of pigmy seahorse and four new species records of corals in Australia.

There's just so much to be found on this ecosystem. Well, it's very much an inspiring place. I mean, when you swim across a reef and you see the beauty and the life, this dazzling, infinite array of shapes and colors and even noises. Fish under water make enormous sounds. And you look at these creatures like the manta ray. Anyone seen a manta ray? They're fantastic creatures. And they're all part of this ecosystem. And, of course, the ecosystem is more than just beautiful and important in terms of genetic heritage and so on, it also feeds about 500 million people across the planet, which are often in very impoverished communities that have no other place to go.

And then if you take a look at other values, coral reefs break the power of waves and thereby protect islands and coastlines, so they have another role there. And in addition to that, in developed countries like the U.S. and Australia, they're huge tourist industries. And, in fact, the state I come from, quite ironically, the largest industry is exporting coal. The second largest industry is the Great Barrier Reef. Brings in 6 billion dollars each year in tourism and supports 63,000 families in terms of employment. So these are incredibly valuable systems.

Now this is a beautiful place. But what if I would've told you that it'll be gone in 20 to 30 years. And what if I told you that it didn't have to happen. And what if I told you that it will only cost a little bit to fix. In fact, it's the economic argument, not the environmental argument here that's so straightforward.

And, in fact, that's what I'm going to do today. I'm going to try and show you essentially where we're going. Then I'm going to ask you, you know, that question all, you know, we'll ask that question, now what do we do about this? And then weigh out the options. And it's a no-brainer. And so I'm going to do, oops, I've hit the wrong key here. I want to talk about the reefs end, I want to talk about the way out, and I want to talk about the call to action and that'll sort of, I think, resonate a little bit, although with slightly ADD way of doing it, with the beautiful words that Kathleen was telling us.

All right, well, coral reefs are threatened by a range of different factors and there's overfishing. We're taking the fish off coral reefs. And, of course, this is a real problem because fish are not there just for humans to eat. They actually have all these roles to play in the ecosystem, like keeping the algae down.

We’re also disturbing coastline, so we’re putting agriculture, growing crops that need fertilizer and so on, and a lot of the sediments and nutrients are flowing out into the coastal waters and killing coral reefs. Well, unfortunately I’m not going to talk about those today. Those are very significant problems but the problem that looms extremely large, as Chris told us this morning in his lecture on ocean acidification, is the issue of climate change.

And so I think many people in this room will realize that we need the greenhouse effect. And so when you look at our planet, you can see rock, you can see water, and you can see this thin, fuzzy little atmosphere. Now taking David Gallo’s calculations where he took all the water off the planet, put it into another little planet, Water World, so he had a big rock one and he had a little water one, all of a sudden, well, if you liquified the atmosphere right down, how much volume would that be?

And what you find out is that if you squish all the air into a liquid, so the entire atmosphere, it’s only 12 meters thick. So literally there’s 1,000 times, so there’s a lot less water than there is rock on the planet and there’s a lot less atmosphere than ocean on this planet.

But this atmosphere is extraordinary. It’s actually the reason why we’re not at the temperature that you see on a planet without an atmosphere, which is 30 degrees Celsius below today. I think even Minnesotans would find that difficult. And, of course, it’s added onto your already interesting climate.

But this blanket is really important. And the reason it has the ability to do that are due to the greenhouse gases. But, of course, the problem is, as you’ve heard and if you’ve been in these other lectures, is that the concentration of those gases is changing.

And we heard about CO_2 rising above where it’s been for perhaps millions, if not tens of millions of years. Other compounds, such as methane, a very powerful greenhouse gas, and other ones like nitrous oxide, building up in the atmosphere.

And we know when we look at the signal in the oceans and so on, and we look at what's going into the atmosphere, that this is coming from fossil fuels. We know that from things like isotope ratios and this sort of balance of those. And so what you're seeing over time is the blanket which is very thin and is keeping us warm is getting thicker by these gasses.

And, of course, when that happens, we're now starting to change the temperature of the planet. And, of course, I think also [inaudible] would be incredibly familiar with this little graph down on the bottom there, which is how global temperature has changed over the last 150 years. And what you see is we've gone up about point eight of a degree Celsius due to that extra CO_2, methane that's come from fossil fuels and to a less extent from deforestation and land use change.

Now I also have a role in the IPCC as the coordinating lead author for one of the chapters. This one's on the oceans. And the new modeling that's come out, which is the consensus of probably 40 different modeling groups and nations that come together to do that crystal ball gazing that's really important in trying to inform decisions today.

And so what you get is, when you look at those, when you look at those predictions, you get a bunch of lines like this. Now notice that we're, and I'll try and be fancy here, here's the arrow, so that's the end of the century. And you see a bunch of lines up here that relate to different amounts of heat being trapped so the 8.5 watts per meter squared is the extra energy that's being essentially trapped under that high scenario, which is where we don't take much action to deal with the problem of greenhouse gasses.

And we get onto this red curve, which as you see goes to eight, possibly twelve degrees eventually, many centuries from now. We'll be putting a course on, the world on a course which will take us to these extremely high temperatures.

Now you need to reflect on the fact that just with 0.8 degrees Celsius, we're already facing issues and I'll get to this with respect to coral reefs, but of course we're seeing a wide range of other impacts that are occurring through this tiny change. So now just think about people a couple centuries later, and indeed our grandchildren and great-grandchildren at the end of this century, and think about the trouble that they will have if it's all linear. But of course it's not. It's actually non-linear. So it may be actually a lot worse than just simply what the curve would say.

Now the better scenarios are those at the lower end, of course. And this is where we take effective action on greenhouse gasses and as I'll show you, this is really the only way, the safe route out of there.

All right. Well, the ocean plays an enormous role in the planetary heat balance, in the gas concentration of the atmosphere and if you were in Chris's lecture this morning, you would've heard that 25 percent of that anthropogenic CO_2 coming from the burning of fossil fuels is coming up in the global ocean.

At the same time, over 95 percent of the heat, the extra heat being trapped by that enhanced greenhouse effect, is disappearing into the ocean. So the ocean, in a way, is acting to dampen the climate change signal. It's absorbing. Water has a huge heat capacity so it's able to take in a lot of energy without commiserate change in temperature.

And so this whole system is incredibly important. And so I'm going to be talking about the heat side. The CO_2 side, yes, it's taking CO_2 out of the atmosphere, but as we heard, that causes ocean acidification which is a very scary thing because it will, once you've changed the ocean pH and you discover it's a bad thing, you can't change it for tens of thousands of years because you've got to wait for the weathering of rocks.

And that question I asked on the panel, which, could you change the ocean pH back to where it was by using chemical means is impossible. It's 63 times around the planet with coal trucks of material that you'd have to put into the oceans.

Well, to give you an idea about the energy that’s gone into the ocean, you need to look at this graph. This is basically how the heat content of the oceans has changed. So it’s the added heat you're seeing here on those oceans. So you’re at 40 degrees. You’ve got a certain amount of heat in the ocean. This is what’s been happening as we’ve been trapping that extra heat. And what you see here is that most of it’s going into the ocean, as I said. A little bit into land resources. But the equivalent here of that energy is the equivalent, and you can calculate this, it’s the equivalent of two atomic bombs going off per second going into the ocean.

So it’s this amazing amount of heat that’s being trapped. And, of course, not surprisingly, we’re seeing a very consistent increase in global temperature. Now that said, you still have, and this is a picture of the comparison of 2010 relative to the period from 1951 to 1980. And what you see here is that there are some incredibly hot places such as, you know, Russia. You’ve got a lot of warming at the Poles and so on. But there’s also a very consistent signal in the oceans which is somewhere around 1 to 2 degrees Celsius that’s being sort of, that extra energy’s gone into the ocean and the temperature’s changed by that.

And so, you know, at the start of it, it seems like a pretty small amount of heat, right? I mean, what’s one or two degrees between friends, right? Especially in this place? Oh, it’s minus 32 today. Oh, no, no, it’s going to be minus 30 because we took care of the greenhouse effect. It’s probably not worth doing, eh? Oh, starting to sound like a Canadian. [laughs] I’m not very good at accents, okay?

Anyway, so what I want to do now is talk about my involvement with understanding how those changes were affecting coral reefs. And it starts, and I wasn’t expecting such a complete biography. I was, I, the one thing I did when I, I didn't go to Oxford, was I forgot to write to the professor that I was meant to be studying with at Oxford. And he’d established me a place in Baylor College it was all good. And I, and it was a bit of, you know, I don't really want to break his heart.

And then I got a letter from him and it said, it was 6 months into my PhD at UCLA and he said, 'Dear Ove, Just wondering if you're going to take up your digs at Baylor College?' I was like, oh, my god, what am I going to do. Anyway, I never got to work at Oxford. And I still can't.

Anyway, the one thing that stopped me in my tracks when I dropped into Los Angeles, and I really didn't know whether Los Angeles was on the west or the east coast of the U.S. In Australia we'd been, you know, very much part of the empire and everyone looked to the Mother Ship for education. And everyone thought that, well, you know, the Americans, what could they know? It wasn't that bad but, I, so I ended up in the lab with this guy. And Len did say, 'Come with me to the Red Sea.' And I did sleep on the floor of the, the lab for a while because it took a while for me to get a job.

I could live on $2 a day in LA, which is amazing, you know? You can get a bag of day-old bagels and then every two days you go to a salad bar and you fill up with eggs and bacon and you can sustain yourself indefinitely. But, I should write a book about that, don't you think? I mean, that's pretty useful information.

Anyway, Leonard Muscatine was really the preeminent scholar of understanding the relationship between these tiny single-cell plants that live inside corals that make them, that take them from being animals and make them into being plants.

And I really came into the lab and just, the wonder of biology, this passion that had been there, you know, the, I think it was 20 tanks, I don't know. It's a large number of tanks at home, but I'd always been fascinated by corals, this sort of symbiosis between tiny polyps, that's about a millimeter or two across, and tiny little cells which are a hundredth of a millimeter in size. And these things, the algae down in the bottom there, live inside the gastric tissues of the coral. And they act like chloroplast and they pump out all this carbon. So it's a great relationship because the coral gets all of this energy, and in return is giving the algae access to waste products. And it turns out in tropical seas, which are very low in terms of nutrients, having fertilizer is really important.

So this symbiosis is pretty marvelous because it’s at the heart of coral reefs. Without it, you don't get the energy to lay down the enormous amount of calcium carbonate, which make those reef systems, that provide the support to fisheries, that protect coastlines that are ultimately food and employment for half a billion people, one in every ten on the planet, or one in every twelve. I need to update that.

Now these ecosystems, they seem so large, so robust and everything. And they build the Great Barrier Reef. And you eventually get to this idea that, no, they really are tough. They could appear on that Exxon Mobil poster, you know, Tough or whatever it was, what’s the term, yeah, Tough Mother. I don't know. Oh, so is that rude? Oh, I’m sorry. [laughs]

Anyway, about that time, it was early 1980s. I’m sleeping on the floor. I eventually get an apartment in Santa Monica, it’s all good. But these samples started to come in from the Caribbean, from some of Len’s colleagues. And they were corals which had suddenly gone white over a couple of weeks and in many cases got diseased and died. And pioneering NOAA natural resource managers like Billy Causey were sending these samples to Len to say, well, ‘What’s going on here?’ And what he was describing was this general paling of corals across large sectors of the Caribbean. And so at first it was, well, is it a disease? Because about that time there’d been a disease that had wiped out sea urchins and had a huge impact on Caribbean ecosystems.

Now was it due to pollution? Now what was it? And so at that time, that was really my first introduction to, as it turned out, to an impact of climate change on corals. And so as we went to study these things, there were a couple of things that stood out.

One is that when you looked in the literature, there were references to the odd coral being bleached on a reef. Like you're going along a reef and then there’s one, there's one and so on. But no reports or anywhere of reefs going white, you know, across square kilometers of territory. No report in the literature.

Now that could be because, you know, we didn't see it and we didn't report it and bandwagon effect. Maybe someone discovers it first and everyone see it and so on. But it was really remarkable because when you traveled around and it started to occur elsewhere in the world, there was no reports of it being, and it was so obvious that you’d have to report it. It’d be the dream paper for a PhD student to be able to write up that I saw a reef go really white and so on.

What we also discovered was that it was triggered by one to two degree increases in sea temperature, tiny increases above the summer temperature and you had this impact going on. And as we went through the 80s into the 90s, the intensity and frequency of events increased and we started to see mass mortalities.

So we saw all these things going on, this increase in frequency and so on. 1998 was the wake-up year. This was where, and I still remember this, the first reports cam over in the Eastern Pacific of massive coral bleaching, entire reefs going white. By the time NOAA had contacted us with the reports on hot water on the Great Barrier Reef, you’ve got to look for coral bleaching, we had the worst case of coral bleaching ever. Half the reef, which is, you know, it’s 345,000 square kilometers, or, sorry, the park’s about 4-, 375,000 square kilometers. Half of the corals in that park had bleached.

It then turned up in the Western Indian Ocean where most reefs from the Maldives, Seychelles, to the east coast of Africa had bleached. And then as the Northern Hemisphere summer came along, Southeast Asia bleached, the Red, parts of the Western Indian Ocean in the Northern Hemisphere and then the Caribbean had its worst case of bleaching.

And by the end of that year, there was a global loss of 16 percent of the world's corals. 16 percent. And in some places, like the Western Indian Ocean, they lost half their corals.

Now, I know we have things like the pine bark beetle in North America. But just imagine if you woke up one morning to find that in the last 12 months, you'd lost 46 percent of all the trees in North America. And that's the equivalent. Corals being nailed in this way are like removing trees. So it was really, you know, everyone was concerned, that this really nailed the idea that it was due to temperature.

And one of the most important parts of this was that it's not just about corals. Corals are that framework into which all those other species sit. So when you remove that framework, you remove the habitat of the fisheries, the biodiversity. And this is just a case where a reef has been removed by bleaching and a whole range of different impacts. What you're left with is something that doesn't have any fish.

And I'll go back to that original photo. This is sort of a pretty healthy reef outside my lab on Heron Island. I'm trying to say that I have a lab on Heron Island. You heard that a couple times, I hope. Getting jealous? [laughs] Well, it's something for the people that are coming into the career, pick your study site carefully. I think that's been said already. Coral reefs have never let me down.

But anyway, so what happens is you lose the structure and you lose that function and this is now being quantified by Shaun Wilson and others who've compared reefs that were affected in 1998 to different extents and looked at the fish communities. And what they find here is that fish like this butterfly fish that eats coral, has to hide in coral and so on, disappear so the, anything below the X axis here is a loss. But then some fish did better. And it turns out that fish like this guy here, which is a parrot fish that eats algae, so they're not so tied to coral.

But what these guys have found since then is that even fish like parrot fish that don't eat coral as adults and aren’t so dependent, the juveniles are often hiding in amongst live coral and they need a complex substrate. So this is probably an underestimate of the impact of losing coral on reefs.

And this is just to give you an idea of the scale of these things. This is another bleaching event on the Great Barrier Reef in 2002 where 60 percent of the Great Barrier Reef was affected. And what you’re looking at here are these corals that have lost their symbionts. You’re looking at a lot of corals that are dying. We went here with journalists that with [inaudible] from the really foul smell coming off this. And what you're looking at here is a graveyard of corals. And if you go back to this place today, which is on the Keppel Islands, you’ll see probably about 10 percent of the corals you see in this picture today. So it’s a huge impact.

Well, as I said, we know that it’s largely due to temperature and the reason that we know is the excellent work of the NOAA Coral Reef Watch Program, flying satellites that can detect the skin temperature of the ocean and looking at, over long periods of time, they can actually detect anomalies in sea temperature. And this is 1998 when we had the 50 percent of the Great Barrier Reef affected, where it’s yellow it’s about a degree warmer. Where it’s orange, it’s about 2 to 3 degrees warmer than normal.

And you can see the coast over which the Great Barrier Reef sits had a lot of heat, a lot of heat anomalies there. And this is 2002 that I just showed you that picture from, and this is a real-time build up, as you go into our summer and out into the autumn, you can see also you’ve got this large amount of heat, extra heat in the water.

And, in fact, it turns out that that relationship between the heat anomaly, the temperature anomaly and coral bleaching is so good that there’s a predictive service or a, I guess there’s a forecasting service that NOAA runs, which will actually 80 percent of the time predict what’s going to happen to a reef based on those temperature anomalies. So that’s really the proof is in the eating of the pudding, right?

So the other thing you could do with these sort of data is that because it's so predictable that you get to a certain temperature in a certain region and you're there for a certain period of time, you can actually then predict where there's going to be bleaching, severe bleaching, or mass mortality based on that temperature anomaly. And here's some data from Tahiti, which I published some years ago, showing summer, winter, you know, a bunch of years from 1981 to 1999 and here are the bleaching events, the arrows, those arrows there. And you can see that it gets above about 29.4 and you get a bleaching event.

Well, you can take that number and say, okay, if I go to the modeling community, those people that know about what temperature is likely to do in oceans as we go forward in an enhanced greenhouse world, when will it exceed that temperature, that temperature we know causes coral bleaching?

So I remember doing this in the Blue Mountains. It was a lovely day, we had our first house, we had our first child. And I was sitting there on a Sunday afternoon, fiddling around with those numbers that I'd got from the climate modelists and so I put the numbers into the model.

Here's the trigger for coral bleaching and here's what they said. And it kept on, every time I ran, you know, put the two data sets together, I found that the temperature of oceans on a doubling of CO_2 exceeded the threshold for coral bleaching at about 2030, 2040. And I thought that's got to be wrong. I was thinking it would be like 150 years into the future. I'd get my time on the reefs and then it'd be good. But, what, yeah, I know, very selfish. Kathleen'll probably castigate me later. [laughs] And quite rightfully so. I've reformed.

But what I found was that this, this, that the climates that we were creating with relatively mild amounts of warming were presenting huge problems. Now about this time, we also became aware of ocean acidification. And this, of course, is the evil twin of the warming effects of CO_2 and it's that CO_2 going into the ocean decreasing the carbonate iron concentration, changing the pH and then having a whole series of impacts on things like corals, and as we know now, the navigation ability of fish and other organisms, really big effects.

Well, one thing to sort of do here is to run those experiments yourself. And so this is a picture of Heron Island. As you see, it’s an awful place. There’s no football field. There’s no supermarket. There's sand that can get in your eyes. And there’s sharks.

Well, it’s the most beautiful place on the planet. If you ever want to see something on the Great Barrier Reef, Heron Island is the place to go. And that’s where we have a lab. And what we’ve been doing, and this is Sophie, the ever-suffering, but we’ve been collaborating on a bunch of experiments. We have been simulating future worlds to see whether these associations that come out of the models are in fact true.

And so down in this corner here is what we call the jacuzzi experiment. These are containers about the size of Jacuzzis in which we’ve got water flowing in and flowing out, so it’s being pumped straight from the reef crest and so on. We put into those experiments little mini reefs, so we’ve got corals, we’ve got fish. We got a whole bunch of things. So we make a little part of the reef. And then we manipulate the temperature and the CO_2 content of those experimental chambers. And we’ve replicated and done all the things you have to do statistically. And the results are quire remarkable.

Here over in this corner there, there I should say, we’ve got sort of some of the details of the experiment. And basically we’re taking the local temperature and we’re adding on what you would get if you went down that red line that I showed you into the future. So you add 5.6 degrees heating. You add a certain amount of CO_2 to that versus preindustrial, so we actually take out CO_2 and cool the chambers. And then we’ve got today, which is about 1 degree warmer. It has 100 parts per million more CO_2 and so on. And then we run these simulations. And so I wanted you to just, and these experiments run for 8 months so they really take a long time.

[inaudible] mouse, here we go. So firstly, here's the preindustrial. You can see some corals, it's over 8 months. These are sort of weekly photographs and here's what happens. So you can see the corals still stay brown. The sea cucumber is enjoying life. They're very cerebral animals by the way. See that black one there, that's the sea cucumber I should say. Let me see here. Yeah. There, there's a sea cucumber. But it's a little ecosystem.

The other thing to notice is that over here, this coral here is a very sensitive coral. It's growing like crazy. You see all those little branches? They're new branches. So this is a very healthy coral reef. Interestingly, we did see a little bit of bleaching and that sort of shows that that's part of the ecology that's there. It's just how much bleaching you get.

Now look at that red scenario. So we start off, you can see the coral suddenly went white as the temperatures are coming in. They have that extra added temperature to the signal. And you can see eventually they die. And they get covered by algae. And so what you see here is that there's a coral that actually survives 8 months of this treatment. And that's interesting in itself. So there may be some tough corals that get through this but if you look here, here where we had that, you know, very delicate coral, you've lost, Mr. Sea Cucumber is not there with his madam. It's a very different world. And this looks a lot like what we're seeing in nature. And I think it gives us some confidence.

If we look at the reef accretion rate, so calcification is this important process that corals do and that's how they build the reefs and so on. And the flip side of it is that they will erode over time. And so what you see here is that as you go from the preindustrial to the control, this is very health calcification. There's no dissolution. There's a little bit in the control. But as you get to that scenario that we're on right now, you have very low calcification and a lot of erosion. And so if you think about the range here, reefs are basically slipping away.

All right. So this future, these are those data I was talking about in terms of temperature. You've got the bleaching threshold, 29.9, and then you've got what happens to sea temperature over time. And so you have to ask the question, if we already know that little excursions like that have a really big impact on coral reefs, how are we going to get to a point where the winter temperatures may be above today's summer temperatures. And that goes for a lot of different parts of the world, Phuket in Thailand. The South Coast of Jamaica.

All right. Well, that was then, that was in 1999. Since then we've had various assessments, updating the models. This is one that was led by Simon Donner, same conclusions. When you get to just a couple of weeks ago, we published another one based on the current IPCC model projections, you find that coral reefs are in trouble if we get to about 2 degrees above the preindustrial, then we have trouble.

And of course this is what this means in pictures. All right. There's today, beautiful reef. Here's what we would be looking like if you get to that scenario that I was sort of, corals aren't doing very well, they get atropated [sounds like]. And of course if you get to 3 degrees, you're in that vein where corals are no longer keeping pace on reefs. Reefs are breaking down.

All right, so is this really happening? And this is literally 2 days ago. The Australian Institute of Marine Science has published a really important paper where they took their long-term monitoring data from 1985 to now and for a long while that data hadn't been sort of properly at, the bias for sampling hadn't been taken out of it. And so they published this in the proceedings of National Academy of Sciences. And I think it justifies this title that I had for this talk which is that I think corals are going, going, gone. All right. It was published yesterday, couple days ago. [laughs]

Anyway, so what you see in this corner is the percent of coral cover across the entire Great Barrier Reef at a whole range of different sites. And you have the time, '85 to 2012. Coral in the early 80s was about 25 to 30 percent of the bottom of the Great Barrier Reef. A decade or so later, it hadn't dropped by much. It was down around about sort of 22.5. Look where it is today. It's less than 15 percent. And if you run this out, the conservative conclusion here is that we won't have coral on the Great Barrier Reef within the decade. It sounds awfully like artic summer sea ice, doesn't it? That's also dropping incredibly fast.

Now interestingly, they looked at the causes. Because they're doing these regular surveys, they're having a look at what was there and the crown-of-thorns starfish, have you ever heard of that thing? This big coral predator, big starfish about that big, has 2 million babies each year that eats coral. What they found was that persistent grazing by the crown-of-thorns eating coral was a major player in this. In addition to that, cyclones, we've had three of the really biggest cyclones in the last decade, a little like what's been happening in the Gulf of Mexico in Southern United States. And then of course bleaching.

And so you might say at first, well, bleaching's only a small part of this so it's not mainly a climate issue. But I think what we will find, and this is speculative in some respects, but if you take the complexity of climate change and you say, OK, well, here we have human emissions. It's increasing temperature. I think that's a fairly solid data set and model.

We have thermal stress, these extreme events are building up. We're getting the loss of corals from that. So that attribution chain is quite, quite solid. It's probably also fair to say that the evidence for stronger storm systems as you heat up the ocean, as we heard from some earlier talks yesterday, that if you heat up the ocean, you get bigger storms, you get more violent impacts on reefs and they're taking a lot longer to recover from. And so this pathway is probably not too bad.

Now the crown-of-thorns has an interesting connection to climate change. And I think this is where we're going to go in the next couple of years. So this is really speculative but, so we know for a while that there's been an intensification of the hydroelectrical cycle, which is just simply a warmer world. There's a transfer of water into the atmosphere. About 6 percent more water. That creates bigger deluges. And so we've been seeing that over the last decade or so, and including in Australia. In the city I come from, we had the worst flooding ever where two-thirds of the state was covered by water, about 2 years ago.

Well, for a long time, they've known that when you have floods and disturb coastlines, leaking nutrients and sediments into the ocean, the crown-of-thorns takes off about 2 or 3 years later. So I think what we're going to see is this attribution chain become actually something that's connected to climate change as well. And the point being from this is that it's the complexity of climate change which we're discovering that small changes can change a whole bunch of different variables that then on complex systems like coral reefs have big impacts like the loss of coral.

All right, so the way out. And this isn't just because I want to be an optimistic person. I actually am optimistic. And I'm optimistic because we are a society now that has a billion people connected up online. We have an ability to look backward in time with a certain surety. And forward in time with an amount of accuracy and understanding. And technology is at a state which is just leaping and bou-, goes in leaps and bounds. So I'm a little bit of a technological optimist.

But I also am very much of the mind that it's not just about technology. So I am talking of the technology thing and then I'm going to talk about the hearts and minds and I'm going go outside a very, my comfort space. Because I'm meant to be a dry old scientist and I may start crying on the stage here so I just want you to know that.

All right. So what are we going to do about this? Well, there are two ways to approach a climate issue. One is to mitigate, solve that CO_2 problem or the other one is to adapt. And at the heart at that decision currently is the issue of dollars. So let's do a worked example to see whether one is more expensive than the other.

All right. So the first one is we could reduce fossil fuels, we could switch power supplies, build solar thermal, get geothermal going, do all that stuff, bury CO_2, stop deforestation, grow trees, cost carbon correctly as a pollutant. And we could limit those other greenhouse gasses. We could limit the amount of fracking, for example. I mean that in the best way. [laughs]

Okay, so what would that cost? Well, it's interesting, the IPCC in the fourth assessment report had a group that focused on this issue. What would it cost to do that switch? Now what you hear of course is it's impossible, it's too expensive, it's going to send us broke. Well, nothing of the thought. When you look at their numbers, this is the sort of table to focus in on. It's really a summary of several chapters of intense scientific and expert consensus.

And what you see there is that to limit CO_2 to I think it's 465, CO_2 equivalents, it's going to cost about .12 percent of GDP growth over the next 50 years. So that doesn't sound like a lot of money but then GDP growth's probably huge, right? It's like really big, so maybe that's a lot.

Well, if you look at that, and so what I've done here is I've gone, well, we want to do better than the 465 CO_2 equivalent, right? We want to really address this problem as rapidly as is possible. So we've quadrupled the numbers here and so 0.5% of GDP growth over 50 years would be about 14 billion dollars per annum for the world. Two bucks per person each year to save the planet. Okay, well, not everyone has our wealth or lifestyle.

But I think even if I was asked to pay 20 bucks annual subscription to the Earth, I'd pay it. I mean, it's cheaper than National Geographic, isn't it? [applause] But it's true. So it's cheap. All right. Okay, but still, you know, those economic rationalists will say, yeah, but, you know, that's much more expensive than adapting, that's much more sensible.

So, oh, and I just want to point out that if we thought we had numbness before, your country of course came forth with the huge assistance to Europe post World War II. And of course this was, had some motivations but it was one of the great charitable efforts of this country to Europe. And of course the price of that was a lot more per head of population than the $2 per year for the planet.

So on this basis, it doesn't seem a lot, but let's see adaptation. Okay. So here's my experiment. Here's the damaged reef. And I haven't done anything about climate change. I couldn't get away from the couch and the kids were distracting me. So I decide I'm going to replant the reefs in 2030, 2040 when they have disappeared. So what would that cost?

In fact, I'm going to give you a simulation. Have a look at the simulation. This is what I'm going to do. See that's pretty clever isn't it? That's going backwards. That's a site on the Queensland coastline, a picture taken in 1900, the first one was in 2000. But what I've run it backwards to say, well, if we could maybe recreate this reef by planting corals. So what would that cost?

All right, well, I did it. And, you know, it's funny in science, you get bold after a while. I've been waiting to be cut down on this but no one has. It's that ego game. So there's 40,000 square kilometers of coral dominant habitat on the Great Barrier Reef. So the plan would be to plant a new coral colony every 5 square meters of that 40,000 square kilometers. That'll cost me 40 billion. That's one species. Given there's 560 different coral species that's found in and around the sort of Western Pacific and the Great Barrier Reef, I might want to do, oh, I'll do another 24. Well, you get to a trillion dollars really easily. So that's a trillion dollars, which is a lot more than the billion dollar cost that we saw.

So I think you can safely say, of course I'm only saving the Great Barrier Reef. I'm not dealing with agricultural issues. I'm not dealing with all the other problems, the sea level rise, and all the other things. So you have to say to anyone who says, oh, it's better to adapt or to not quite deal with the mitigation problem, we have to deal very firmly with the mitigation issue. The evidence is there. This is not activism. This is just the hard facts. So, okay, let's go and see where we go now.

The next question is, well, if you're going to mitigate, by how much? Now when you look at the climate models, and these are ones done by Malta Mindshousen [sounds like] out of the Potsdam Institute, which is one of the leading institutes in the world, here's our current pathway of CO_2. That's the, it's equivalent to the RCPA point five. Here is where we limit the amount of change. We keep the concentrations below about 450 and we don't allow the temperature to rise more than 2 degrees Celsius.

That's a safe climate because the evidence that we have right now, and it's called the guardrail, this is the guardrail to say, beyond this gets pretty difficult. And you look at the risks there. You know, loss of the Great Barrier Reef, the Amazon, Alpine region, food security, water crises, sea level rise and so on. And you've only [poor recording] talk to the insurance companies of the world to understand what that really means. And I'll talk about a collaboration with an insurance company. They are, they get this. Because insurance claims are doing this even after they've been adjusted for changes in the price of currency and whatever.

So that's our ambition. There's that line there. That would be good, as soon as we stabilize things, things can catch up. So what would we have to do with emissions? We would just turn them down by 40 percent? I don't know. What would it be?

Well, it turns out, we have to aggressively reduce emissions from now by sort of 3 to 5 percent over the next coming decades or we will go down that red line. And, again, that's what the evidence is telling us. So that sounds awful. What's the good news?

Well, the good news is outside. And I'm not getting poetic. I'm still an ADD scientist. I wish I could. I'm so jealous of Kathleen. You know, that was just fantastic. But anyway, this thing here puts out 10,000 times our energy needs. And of course the amount of territory you'd have to put into solar fields to trap enough energy to run the planet is something smaller than this. And I don't want to insult people in Arizona but it might be a good place to [laughter], I'm safe aren't I? Yeah. Okay. [laughs]

And of course the other good news is that there are huge amounts of alterative technologies and when you ask that question, so that little mind experiment about solar and North America, it’s well known but it’s not realistic, right? You couldn’t take that and put it into action.

But the International Energy Association has looked at these, the potential for different renewable energies and finds that we’ve got more than enough, six-fold more than we need to power the planet. And, in fact, in our institute, we’ve been putting this into practice. And this is Australia’s largest solar array, rooftop array. It’s 1.22 megawatts, which I know there are much bigger ones here in this country. But we’re a small country, we’re starting.

But what was amazing about this is this was more, in many ways, when the renewable energy guys in my institute came to me and put this together, this was really like psychological counseling. Because these solutions are, this thing pumps out that energy, right? But it pays for itself in 7 years. But it’s got a life of something like 25 to 30 years. So we’re planning to put in another three next year and hopefully take out 50 percent of the emissions of the university within 5. Now that’s amazing that a university can do that. And, of course, the government leading with the right instruments and so on and making it happen as long a-, you know, with the people, this is possible.

We’re also moving into Australia’s first zero-carbon, zero-waste building. This is going to be my headquarters from April next year. And that’s a, that’s a building which has a clever skin. It opens and closes. It’s got ways of dealing with, you know, the flow of air that don't require the huge amounts of energy and supposedly, it will be comfortable. Although, I must admit, I’m a little worried. The architects told me that it might be above the comfortability index for 20 days of the year. But I don't know whether that means we have to be seen in leotards inside the building. But I have to talk to the president of the university about that. [laughs]

This is a quote a really like. It’s from your entrepreneur Bill Gates. And I think this is one of the things, this is a wild card that we’re dealing with, and that is that we always overestimate the change that will occur in the next two years and underestimate the amount of change that will occur in the next ten. And his advice is, ‘Don't let yourself be lulled into inaction.’ I think this is really, you know, very wise advice.

This is a graph to watch as well. Also eluding to the computer industry as well and this is the plummeting cost of solar PV. So you’ve got the, the data, the time, you’ve got the cost per watt hour and, or per watt, and so that’s decreasing. And it looks suspiciously like Moore’s Law if you were to flip it up the other way. Now is, and of course at $2 a watt, which it’s close to, it becomes competitive with the other sources of energy.

Now Moore’s Law is an interesting one. Do you know Moore’s Law? So Moore’s Law is this idea that computing power, the number of transistors on a circuit board has been doubling every 18 months and it’s been constant through, absolutely constant over time. And it’s a law. Well, if this were true, then plotting on a log scales, you get a straight line and that’s what you get with the plummeting cost of solar. So if this is following Moore’s Law, then by 2030, the cost per watt will be 50 cents. And we’ve got no other reason to believe that won’t happen. And I guess that’s technology.

But this is what oil prices do and they will continue to do as demand goes up. If you have a finite energy source, be that uranium, yellow cake, or oil and gas, eventually the prices will go up quite steeply. And so it’s, what would you want? Would you want the plummeting cost as a politician, or would you want the rising cost? And, of course, that comes into the decision you make about what infrastructure to build today. Because you can’t build something and change it once you’ve started to build this stuff. You either build for oil and gas or you switch now knowing that that price will be so much cheaper in the future. And that is at the heart of employment and manufacturing.

If you have expensive energy, you don't have manufacturing because they go elsewhere and you don't have job.

All right. So the call to action. This is a big problem. Seven billion people we want to turn around. And so we’ve been quite proud of getting out to several hundred people and talking to them. But if we're going to solve this problem, we need to get out there to a billion people, and is that possible? Because we've got to get out to Russian grandmothers, Ethiopian businessmen, Australian teens, you name it. We've got to get out to those populations to drive the change that we're talking about, to get those hearts and minds.

And of course it comes down to how many people have done this? So who's dived on a coral reef? Okay, that's about, I'd say it's 5 percent. Are people in agreement with that? So this is, this is unusual to this statistic which is 99.9 percent of humanity hasn't been diving on a coral reef. So why would they care?

You know, why would all of these people care about reefs thousands of miles away? We're told we're all connected. But, you know, a coral reef? What's that? I saw it on Sir David Attenborough once. It's overrated. So it's getting out to these people and as, and this is where it's really clunky, it really is coming down to you've got to get to the heart because we have 97 percent of all experts have been telling us that we have a major problem with climate change and we're not responding. We're not getting it as we've heard already today. We're not getting that message. So it's got to be the heart. It's got to be the mind, and it's got to be the action. So how do you do that?

Well, I think we've started something a couple of days ago which I think, I like to think of it as a bit of a game changer. We've gone into partnership with a major insurance company, Google, and a bunch of underwater photographers. We're the science guys, they're making the project happen, and communicating and engaging it. And so with Google, and this is some of the tools and the science, I'm not going to tell you much about the science. It's about detecting at a global scale using rapid photographic techniques and computer learning to analyze those transects and so on. It's very futuristic. Don't you think that looks like Jacques Cousteau? That's why I'm involved really. Just so I can wear the flippers.

And of course these automatic ways of detecting change are important in everything and not to demean the science, the science is great. But the next, if I can get there, okay, what we launched was street view for underwater. Yeah, I thought it was cool. [laughs][laughter] So I recently stood in front of the TED audience and I said, you know, how many people went diving. And then I said, who wants to come diving with me? Who wants to come diving with me? Don't [applause] so all these people put their hand up and I said, and the best thing about this, you don't have to do any training and you can be in your armchair at home with a cup of tea in your hand.

And so this is essentially what this project has done. I'll just play you a couple of clips here. There's a bit of sound So here you go, you want to go diving on the Great Barrier Reef. So what the project is creating from the science side, which is rapid photographs, are these 360-degree street view like images over kilometers of reef. And by the end of the year, we launch the actual collections in progress at the moment. But by the end of the year, we'll have 20 sites on the Great Barrier Reef where you can literally view 50,000 of these images and come with us on the journey of science of discovering the impacts.

See Crown-of-thorns devastation firsthand. See the impact of coral bleaching. And we think this is going to change things. The other thing we're doing is to, let me see if I can get this going. They're pretty big files. But the other thing is to actually make science live and . . . let me just have a fiddle here. Well, look, this, I'll have to show you later, but basically we've got Google Plus, Live Hangouts, divers connecting up with audiences. So last week we connected a diver on Green Island on the Great Barrier Reef directly to the Blue Ocean's film festival in Monterrey. And people were interacting directly with this crazy guy which I was hoping to show you a picture of. But it's really making science matter. People relate to it and so on.

So instead of that 0.1 percent, we'll have, we hope, a lot of people do the-, now is this working? That's the big question. Well, we went out to 1.07

billion people. We have 1.8 divers that have dived on the Great Barrier Reef now on the sites that we have. And we have over 1.6 million Google Plus followers. That's the sort of volume that we need to get to if we're going to turn this planet around in what I call, and many others do, the critical decade. And there's reason for optimism. Because if we make the decisions today, take us on that emission pathway, everything's good. But 10 years from now, if this hasn't happened, in fact, I'd say 5 years, I'm no longer an optimist. Thank you.