

Annex EF44 of Dr E J Fordham Interested Party – Unique Reference: 20030698
EN010106 – Sunnica Energy Farm

**Transcript of the final interview of the late Professor Sir David MacKay FRS,
recorded 3 April 2016, 11 days before MacKay's death on 14 April 2016.**

In conversation with the journalist Mark Lynas

Transcribed by Dr E J Fordham based on publicly available video recordings.

Final interview of the late Prof Sir David MacKay, 3 April 2016

Derived from video found at: 

**David John Cameron MacKay
Recipient of Breakthrough Institute Paradigm Award 2016
In conversation with Mark Lynas**

Transcript from video recording

Minor speech fillers and hesitations omitted; sentence breaks according to sense for readability, but as far as possible verbatim as recorded.

CCS= Carbon Capture and Storage

MacKay: where's the clapper board ... [claps hands]

Lynas: [laughs] May I ceremonially present to you the Breakthrough Paradigm Award for – what year is it? – 2016 – there we are, it's in this box somewhere [presents award to MacKay]

MacKay: Thank you – oh it's heavy – thank you very much; this is a real honour [unwraps box] – Crikey – [lifts out glass sculpture; shakes hands with Lynas] – thank you very much. Thank you

Lynas: Everyone knows about you for your work on energy and I think that's probably what brought Breakthrough in your direction. It's just this amazingly transformative book you wrote called "Sustainable Energy – Without the Hot Air". That's how I found out about you. Can you just give us a sense of your career you went from mathematics and you were doing software engineering and all these amazing things and suddenly you ended up writing this book about energy?

MacKay: Yes, originally my main research interest was how brains work and how to make machines that are useful, a bit like brains can be. I had this ambition to have computers as smart as cockroaches. I spent most of my career working on communications systems, learning algorithms, software to help disabled people communicate more efficiently, so you can write in any language with any muscle. But I worked in a Physics department so I taught Physics, and I found myself perpetually irritated by what people were saying about climate change action and energy options. On the radio people were saying: oh yes we waste energy, people have done a survey of British energy waste; and lots of people leave their phone chargers plugged in. As a physicist it drove me crazy that people could be so out of proportion just not understanding that the phone charger is absolutely tiny compared with other things like transport, heating, food, the food we eat the energy from those things is so much larger – did I say flying ?

And then I was teaching in Africa, at a place called the African Institute for Mathematical Sciences, and all the students had to give little presentations, five minute presentations on a topic that interested them. One student gave a talk on climate change and climate change action.

Then this Polish lecturer who was one of the other staff of the Institute piped up at the end of this little five minute talk and said: this is rubbish – the talk had been about how we can use renewables to quantitate climate change action – he said: that is rubbish, even if we covered the whole earth with solar panels we wouldn't be able to power humanity. And I said "well that's wrong" – and then I was a bit embarrassed because I didn't know by what factor he was wrong. I had heard Mary Archer give talks about the future potential of solar power so I knew solar power did have – was bigger – than humanity's consumption, at the moment. But I was embarrassed because I didn't actually know by what factor.

So that day I then said ok I've got to sort out my embarrassment, I'm irritated, I know people are talking rubbish, but when I tell them "that's bullshit" I don't actually know – I haven't got the numbers myself. So let's work out the numbers.

So he was wrong. Famously people say, over and over, the amount of energy hitting the earth in one minute is bigger than humanity uses in a year, or something like that. Which is true. But actually the ratio of one minute to one year is not that big a factor. It doesn't give you much room for manoeuvre. The actual ratio of human consumption ... I like to do it in Watts per square metre because that's something you can transfer to cities and countries and so forth. Human consumption, worldwide on average, is about 0.1 W/m² of land area; incoming sunshine – in a place like this – is 100 W/m² on average – global average is perhaps more like 200 W/m² – so the ratio of 200 W/m² to 0.1 W/m² is just a factor of 2000.

So yes, Sun is enormous! It's enormously bigger, it's 2000 times bigger ... now is 2000 times bigger actually enough that you can say it's all going to be easy?

Well, no, because if you say actually it's unrealistic to solar-panel the whole of all the oceans, so we've lost a factor of 3 there. Maybe if you say ok let's just stick with all the land? All the land? No? Maybe we want some of it for agriculture ...

Lynas: The ice caps, rainforests ...

MacKay: ... yes, maybe some of it's inconvenient ... and maybe some people actually want to have things like Grand Canyons and the [*inaudible*] and beautiful places and maybe we want Nature to carry one existing. So you can't just solar-panel the whole earth.

And once you start being a bit realistic and say ok maybe we'll allow ourselves to solar-panel 10% of the land area and the actual efficiency of the solar panels is only going to be maybe 20%. The moment you put these bits of arithmetic, these simple bits of realism, then you realise actually it's a pretty close thing, if you want the sun to power humanity. Yes, it's technically possible, but you're having to use really large areas, you have got to build something really big.

So I wrote a page then at this mathematical Institute; it was called "Order of Magnitude morality". It was the first stab at thinking about arithmetic, and how we live today, and how we could live without fossil fuels.

And then a friend, Matthew Brownley, read it for me – he was working for Greenpeace at the time – and I had focussed on Solar, and he said: why did you focus on Solar? And the reason was that Mary Archer had given a convincing talk that had led me to assume that Solar was the basic thing to focus on for a post-fossil fuel option. So he said: look at all the other options as well.

So then I did that and I came back to Cambridge and taught some courses – some lectures – where I just went through options one at a time and I did back of the envelope calculations and put everything all in a single set of units, and that turned into the book.

I put everything in kilowatt hours per day per person [kWh day⁻¹ person⁻¹] and it was just amazing to actually work out the numbers. I wasn't trying to bias anything – each class we'd say ok let's draw the coastline of Britain, measure how long it is, estimate how much Wave energy is coming in, let's make estimates of Tidal energy; let's look at rainfall, you look at every one of these potential sources of Hydroelectricity and Wind and so forth – most of which are coming from the sun originally, they're just third-hand ways of collecting Solar energy – and again and again when you started by saying what's the fundamental limit, what's the actual physical flow of energy that's available and then you put some reality factors in to say, well, you can't get all of that, can you? – 'cause that would destroy Nature and would require turning the whole country into a Hydro facility or whatever.

You put in some realism, and then what kept on coming out, again and again, was if you have a optimistic but realistic view, each of these sources, for the UK, I reckon, could give you *maybe*, if you pushed, 2 kWh day⁻¹ person⁻¹ . And it just kept on coming out like that, that Wind, it seemed credible to me that if you pushed hard at Wind power, on average it might be able to get 2 kWh day⁻¹ person⁻¹ . Tidal power, really big programme, 100's and 100's of km² of Tidal facilities, another 2 kWh day⁻¹ person⁻¹ . And it was 2 and 2 and 2 ... all these different renewables were coming out ... that's just what popped out.

And I found that just really striking. Our current consumption in the UK and in typical developed countries is 125 kWh day⁻¹ person⁻¹ . In America it's 250 kWh day⁻¹ person⁻¹ . And arithmetic says that 2 plus 2 plus 2 ... plus 2 plus 2 ... is *not* 125 ! It's not 250 either.

There is this appalling delusion that people have that, oh yes, we can take this thing which we are currently using to deliver 1% of all our energy and we can just scale it up. And oh, if there's a slight issue of it not adding up, oh yes we'll do energy efficiency.

Because oh yes (*ironically*) I've heard you can have energy harvesting devices on your body and generate energy and charge your mobile phone charger ...

– there's so much delusion and I think it's so dangerous for humanity that people allow themselves to have these delusions that they're willing to *not* think carefully about the numbers and the realities, and the laws of physics and the realities of engineering.

So the book was born out of anger and the feeling that humanity really does need to pay attention to arithmetic, and the laws of physics, and we actually need a plan that adds up.

And it isn't just the land area issue which I bang on about quite a lot in the book – that's one of the themes – but there's the intermittency issue as well that we need ... people want energy, in a modern society, when they want it, and so you've got have supply and demand matching.

And again there's a new delusion spreading through the world at the moment which is oh yes Solar is coming down in price, Wind is coming down in price, and Batteries are coming down in price as well, and people seem satisfied with [just] these simple statements that the prices are coming down, so it's all going to be fine.

But they haven't done the numbers to think through actually how big the Batteries would need to be if you wanted to do a Solar and Batteries-only solution - there is this phenomenon called winter and in some places you know it's a real thing ... in Britain the average intensity of sunshine is 9 times smaller than it is in the summer. Winter is 9 times darker, and so the size of Batteries you actually need for this magical free Solar and free Batteries – you need just absurdly large Batteries and what actually needs to happen to the price of the Batteries for that to become a realistic option is that they've got to come down by a factor of 100 or so.

Lynas: Have you read the Ecomodernist Manifesto and how do you feel about ecomodernism as a sort of idea ?

MacKay: Personally I do like the Ecomodernist Manifesto but if it's a polarising thing that stops people having constructive grown-up conversations then I'd rather not take it upon [inaudible] – I'd rather say, let's carry on using arithmetic, having constructive grown-up conversations – building a consensus. I think the ecomodernists – you know I think it's a very sensible outcome for that consensual conversation, but the most important thing of all is to try and keep everyone participating in a consensual, numerate, conversation based on things like the Global Calculator.

Lynas: Being numerate is just the first step and then you have to actually decide what you want your priorities to be and that comes down to values and politics and political economy and things like that, right ?

MacKay: Absolutely – I genuinely would be content with any plan that adds up. Having spent 5 years in Government seeing how difficult it is to get some types of policies through, seeing how important money is, and cost is, I now have views on what I think would be a good outcome.

But if I were to nail my colours to the mast and say ok I advocate this solution: lots of this, lots of this, a little bit of this and none of that, then the way human dynamics works is you lose the trust of a whole load of people because they'll just say oh he is – [to Lynas] you know they've done this to you – you're pro-nuclear, you must be being paid by the nuclear industry, I'm not going to listen to you more. So I've always tried to avoid advocating particular solutions, but maybe the time is coming that I should call a spade a spade ...

Lynas: Come on, tell us then, what would be your ideal then? What kinds of things do you want to see more of and what kinds of thing do you really not want to see?

MacKay: It's always country-specific. So for the country, the UK, I think, we want a zero-carbon solution and it has to work in the winter. And now if you just follow the logic through and you say ok I've got to have something that works in the winter and – what are the choices?

Focussing on the production side here – of course we'll do all the demand reduction which should be said – but on the production side, how can you make your energy?

Bioenergy requires enormous land areas. We're going to have to have some of that, probably, there's Nuclear, there's Carbon Capture and Storage, there's Wind, there's Solar.

The Wind and the Solar are intermittent; the Solar's timing is not well-matched to demand, in this country, and you just cost-optimize and say it has to keep working in the winter even if there's no wind for 7 days at a time and obviously no sun.

You can allow yourself interconnections to other countries that may be having similar issues, you can have storage solutions ... you just cost-optimize it and the sensible thing to do for a country like the UK I think is to focus on Carbon Capture and Storage – which the world needs anyway – and Nuclear. And then if you ask well what is the optimum amount of Wind and Solar to add in as well, then the answer is going to be: almost zero, because if you can make it through the winter with your CCS and your Nuclear, getting through the bits of no wind ...

Lynas: That's the highest demand, the winter of course ...

MacKay: That's the highest demand, and so then there's actually no point in having any Wind or Solar, 'cause if you built them as well, that's an additional low-carbon source ... you know I love wind turbines, I've nothing against wind power, they are the cathedrals of the modern age, but it's actually a waste of money. If you have got a low-carbon solution that gets you through the winter when there's no wind going, it's a waste of money to then build some additional beautiful wind turbines. Just because, when the wind blows you're going either to have to turn those wind turbines down, or to turn something else down that you've already paid for, like the nukes or the CCS.

So that's my feeling of the actual rational thing to do in the UK. And that is based on political value judgments which I don't have to hold are right but that's just my feeling of the way the British public is; they do seem to care quite a lot about the cost of energy, so we should be looking for a low-carbon solution that is low-cost.

If people had different values, if they said like the way the Germans seems to be, oh we don't care about what our energy prices are, it's fine for them to go up, by a factor of 10, then maybe you come up with a different attitude. You say price doesn't matter, let's have the country be filled with Wind turbines, and with Storage facilities, and spend lots of money on Storage – but the scale of what you're requiring, we're talking hundreds of flooded valleys to be able to balance the intermittency of the Wind and Solar ...

Lynas: But if you go on the radio in this country and say "oh, we shouldn't do any Solar" you've broached a terrible taboo and you're ...

MacKay: Yes! And to the credit of the civil servants who I worked with when I went to Government – I may have indicated that they had some bad policies – but when it came to whether Solar should be in the mix they had done the numbers for that already and Solar just wasn't on the table at all.

And the only reason that Solar got on the table was because of democracy, that the MPs wanted to have a Solar Feed-In Tariff. And so in spite of the civil servants advising the Ministers No, we shouldn't subsidise Solar, we ended up having this policy – and there was very successful lobbying by the solar lobbyists as well – so now there's this widespread belief that Solar is a wonderful thing, even though it's highly intermittent and mainly

produces energy in July and in December produces 9 times less than it does in July. You know, Britain's one of the darkest countries in the world.

So that's my answer for Britain.

Lynas: In Australia you might have a very pro-solar answer ?

MacKay: Absolutely. Anywhere where you have got a correlation between solar and demand then it definitely looks like Solar is going to be a really really good idea, and Batteries *are* cheap enough that you can store energy overnight. So a battery solution in a place like Las Vegas, I can definitely see it playing a large role. Society still needs reliability though. Society stops functioning if we don't have a reliable electricity system going all the time. And so for a place like Las Vegas you're still going to want other technologies in that mix as well, so I'd advise Las Vegas to get itself a nuke for example. And the world needs CCS power stations because sucking CO₂ out of the air and being able to carry on using fossil fuels is ...

Lynas: Which is unfortunately going nowhere and has gone nowhere in the last several years –

MacKay: Yeah, that's a disappointment; I was really hoping the UK would be one of the leaders in development of CCS technology for the world – all the models show that it's an essential technology if you're trying to make a cost-effective climate change pathway, partly because it allows you to go on using fossil fuels, and partly because it gives you a way of making a vacuum cleaner for CO₂ using sustainable biomass and putting it into CCS power stations and that's why CCS is crucial and the lack of progress is very disappointing.

Lynas: I don't want to end on a disappointing note! Give us a few optimistic things about what you think people watching this, in this audience, could work on and could be passionate about and enthusiastic about.

MacKay: As we've said I think the Global Calculator is a wonderful tool so anything that can be done to enhance that tool, to improve the way it communicates the information about trade-offs. A good piece of work that could be done to enhance the Calculator could be to make clearer the environmental and social impacts of climate change. At the moment the levers allow you to make choices in the energy system and it shows global temperature consequences and rainfall and various other things; and I think there could be far more graphs visualising, over future centuries, showing impacts on land flooding maybe bringing home the effect of increases in droughts and floods and then that tool could be a more helpful decision support tool to help ordinary people understand the choice between action now and suffering in the future. So enhancing that Calculator is a ...

Lynas: And getting people to use it more I guess ...

MacKay: Yes – what else ...

Lynas: Get CCS off the ground by the sound of it? Not something we can do ourselves but if you think that's an essential technology that we really can't do without then it's important to say that, I think. I think people are beginning to just think, oh well, that didn't work then let's look for something else but ...

MacKay: Absolutely. Yeah. And there are definite reasons for positivity I think electric vehicles are going to be a massive hit just as people switched from old cassettes to modern iPods people are going to discover that electric vehicles are just great and maybe hybrid cars – plug-in hybrids will give them a transition, so they have a bit of security over their ranging anxiety, but they will discover that they're using their electric vehicle almost all the time so that's going to be a very positive development.

So, I'm still delighted how the book has been helpful but I'm also still irritated that these delusions about the easiness of getting by with a bit of [*inaudible*] introduction with a bit of renewables and a bit of batteries and I think there's still a lot more to do.

David died 11 days later.

RIP

David MacKay physicist, mathematician, writer, inventor, government advisor, husband,
father 22 April 1967 – 14 April 2016