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Jamie: This is the Climate Conversations, I'm Jamie Ho. Today I'm talking about climate change and artificial intelligence. As far as the climate crisis goes, we're all looking for solutions, whether it's the pursuit of carbon neutrality or simply trying to push the boundaries of energy efficiency. So what can AI add? Well, all human interventions right now face limitations from monitoring and forecasting to optimising energy use in data centres, buildings and power grids. Could AI be a tool in fighting climate change? Yes, advances in deep learning and in computational power have made AI less science fiction, more non-fiction and here and now. But are there also downsides of using AI to deal with a problem as complex as climate change?

With me today is Markus Kraft, professor of chemical engineering and Director of Cambridge CARES, the University of Cambridge's research centre based in Singapore. Professor Kraft is an expert in using computational models to reduce carbon emissions. And his new book, *Intelligent Decarbonisation*, explains how AI might be able to end climate change. Markus, welcome.

01:13

Markus: Hello, everyone. Thank you for giving me a chance to be on your podcast.

01:17

Jamie: Great to have you. Now I'm going to jump straight into the first question. For the average man in the street, I'll go out on a limb, and I'll say that maybe artificial intelligence wouldn't be completely understood fully, right? In general, we know it helps us analyse data and make predictions, optimise systems. Perhaps before we get into climate change, give us a quick sort of overview of how AI is already being used today as part of our daily lives, that me, not you, wouldn't be entirely aware of.

01:48

Markus: The use of AI, that impacts on everyone, daily, is in the search engines and in customer-facing web pages like Amazon or similar companies. This is where we benefit most of AI right now. In particular, machine learning has played an enormous role. About three years ago, there has been a breakthrough in natural language processing using the transformer machine learning networks. They have also increased our ability to do automatic translation, something I enjoy using almost every day and also try to understand what we are looking for when we type a search request into Google, for example.

02:37

Jamie: So I'm going to jump on the term that you used, obviously, is something that we are quite aware of here in our news room and that’s machine learning, right. To sort of segue into climate change, I'm sure there are machines out there which are learning about man's involvement and attempts to manage climate change. Give us a broad sense, then, how AI and technology in general has already supported our plans, various forms to get to net zero, mitigating the impacts of climate change. What kind of AI is this and how might it apply to a specific area, say our water usage or electricity generation?

03:13

Markus: This is a very open question, and it's hard to respond to. One of the problems with the response is that, what do you mean when you say AI? Different people mean different things when

they use the word AI. The layman sort of thinks something magic happens and you get a fantastic solution out of nowhere. And I don't think this is actually the case if you look at today's technology. Of course, there is a trivial way to reduce CO_2 emissions, and that is just to stop using fossil fuels, okay. But that would have enormous impact on our society and is generally regarded as not acceptable. I, for a start, find it very difficult to go back to Stone Age. So, okay, what can we do instead? It is clear that we have to replace the fossil fuels with something else, and depending on which sector you're looking at, different solutions are coming out. The most simple one was actually in the electrical power networks. Here, many people may have heard of the term “smart grid”, so this is the first example where digitalisation, not just AI, is changing the way we operate. This is partly necessary because if we use different energy sources, so for example the sun or wind power, then we have much more fluctuations. The load on the grid does not necessarily match the input of energy that we have. So we have to look into, for example, clever storage technology, and all these aspects need to be handled by mathematical algorithms. And here we go. What do these algorithms look like? Today, in many cases, because we have so much data, we actually don't need to sit down and do physics. But we could use just the data, and sometimes, and very often we use a combination of the two. And that helps us control the smart grid or make the smart grid smart, which is then helping to secure the electricity provision for the population and industry. AI will come into the control of smart grids.

05:32

Jamie: So I'm going to use the example of Jurong Island here in Singapore to drill down a little bit into how grids are smart, how energy systems are smart, and maybe AI will help them get even smarter, right? In your book, you've written about use cases that are associated with Jurong Island. What did your research find on how AIs could do things from reducing costs to emissions in a major petrochemical hub like Jurong Island and what other applications are being tested here and what holds the most promise in your view?

06:02

Markus: I have to say that if you look at Jurong Island, that is potentially the most difficult problem to solve for a variety of reasons. I personally believe that you will see AI solutions in other areas, in particular in the smart city complex, much earlier. So in Jurong Island you have basically two problems. The first problem is, of course, to supply the energy in a carbon footprint-free way. And at the moment, the energy is supplied mainly by gas power stations, so you would have to – that’s electrical energy, but each big company on Jurong Island has also their own proprietary power stations and we have a lot of oil generators just for safety, so – and backup – replacing the energy would not be straightforward, although you could argue that hydrogen may be the way forward. The second problem you have with the chemical industry is that the products itself have a high carbon footprint both in terms of logistics – transporting them around, and B, they are made out of fossil fuels, you know, so the refineries produce the commodity chemicals that are then going to our products. That too needs to be replaced. So we have a double challenge, so to say. So if you can solve the problem with Jurong Island, you basically are on top of things, which is very exciting. And that's partly why I thought we should look at that. But clearly, I would be lying if I said, we have a solution next Monday, okay, it is a long-term research field. Particular things you can do now are, for example, use the overall network of companies on Jurong Island. So, for example, Company 1 may produce waste heat, which then can be used by another company. You save costs and energy resources by doing so, and we do indeed have the study where we looked into this. We also did a little study just to highlight how difficult the problem is where we said, okay, if you wanted to go to the extreme you could place nuclear reactors on Jurong Island, okay. There are many reasons why

you wouldn't want to do this. But if you were just looking at the CO_2 footprint, then this could be a way forward. But it was more an academic study, also to highlight the consequences if you really want to follow through with the zero carbon footprint challenge.

08:39

Jamie: I would imagine, therefore, it would sound as if in the short term, the very short-term, things that maybe can be improved on within a very unique situation like Jurong Island would be improvements on the fringe rather than, as you say, really huge structural changes. And on the fringe, we're talking about efficiencies in energy usage. How far do you think AI has already helped there and what more is out there in terms of research that can actually push the boundaries of energy efficiency in really intensive environments like Jurong Island?

09:13

Markus: I have two things to say to that. If you look at Jurong Island, you will see most of the companies there are big international companies. So, for example, Exxon being one of them, or BASF and others, they have fantastic research labs. They know very well what are the newest methodologies, they are on the forefront, developing this methodology so they know about it. But equally, you have to realise that the investment cycles in such big plants are actually quite long. There is always a balance between sort of CapEx and OpEx, and that will lead to an additional time delay, although sometimes technology may already be known, implementing them, making the investment, getting a return on your investment, that is what needs to be looked at if you want to estimate the time it takes to completely change the industry. In my view, it also becomes clear that one of the key problems is actually policy making, because policy making will have a direct impact on these costs. Most countries are aware of it, and if you look to Europe, they discuss carbon tax and trading. And I think over the next five to 10 years, it will become increasingly the method of choice to push new technology in to make this investment cycle shorter.

10:42

Jamie: I'm going to switch our conversation to another large company, Google, and you make reference to them in your book *Intelligent Decarbonisation*, where you mention an AI system called DeepMind. It helps cool Google's data centres, and they are obviously quite big users of energy. And it's apparently helped cut energy consumption by 30 percent, it said. Explain how that worked. Will this sort of technology be game changers, in a way, in terms of energy efficiency?

11:13

Markus: It will definitely help. It's not magic. Machine learning has been used in controlled strategies, it depends on the richness of your data. And I'm sure this could be rolled out to other areas where digitalisation has been developed [unclear]. So, for example, last year I was trapped in my German hometown Pirmasens and I thought well okay, what am I going to do? So I decided to contact the mayor and ask them, alright, let's do a smart city. And you have to know that my little hometown, it's just 40,000 people. They are really poor, right, they don't have money. And I said, ah, let's do a smart city together. And as a consequence, they were actually quite open and we had a project which basically optimised the district heat network and we could, by using a variety of methodology that included also machine learning, reduce the cost for them by 20 percent and with that we could reduce the CO_2 impact. And so what I'm trying to say here is what happened with Google is not an exception, it's something that we will see, no doubt, in many more areas. You said, okay, AI is terribly expensive, and if you look at big computer centres, they have a carbon footprint

that’s unbelievably high. And this is true. However, it's a bit like the electric car. People look at the electric car and they think ah, that solves every problem. But it solves only if, and only if, the electricity that goes into either electric cars or in big computing sectors is carbon footprint free. So it's either from solar or from wind or from fusion. Only then, it's not a problem. And in fact, one can say, you know, we don't have an energy problem as such, there is plenty of energy at our hands, you know, what we haven't really managed to do is to get our head around how to use solar in the right manner. And this is a field that has developed enormously quickly over the last few years. We are now talking about perovskite cells with very high efficiencies and here, this is also a very important field for AI. So one of our activities is to automate chemical laboratory, but not just the laboratory, also automate the site, right, so you have robots that perform experiments to find more sustainable synthesis routes for better materials, and we can use machine learning to pick the right materials that will have, in my view, an enormous impact on the development and the efficiencies of solar cells, which then in turn will be because everything will be connected, can then make computing centre, just the ones that Google uses, carbon footprint free. And then off we go.

14:02

Jamie: There's sort of a related point that I would have then is related to the cost of the machine learning, right? Using DeepMind, as my example, it showed that just training this AI system is also energy intensive in and of itself. And there's been studies that find that training a huge system like that could consume significant amounts of energy and emissions as well. Is this sort of something that you keep in mind as you look at research in terms of how and whether there is a trade-off between AI’s own energy consumption and its purpose in optimising energy use?

14:39

Markus: I have three things to say to that. The first thing is that you are right when you say the training of an artificial neural network is very expensive. I’m thinking in particular about GPT-3, not sure whether you’ve heard of it, it is a natural language network. It's also based on this transformer technology that I’ve earlier said that basically has used unprecedented amounts of data. In China, there is a similar network being trained, but you don't have to do the training every time. So you train such a network and then you have to do only minor modification to get uses so the benefit multiplies. Eventually, if you distributed over all machine learning algorithms that are then based on something like GPT-3 or a transformer network, then the energy use is actually not that dramatic. The second comment is, if you look at AI, it would be a mistake to just equate it to the current construction of the neural network and the way we train them. This field is rapidly evolving. In my view, we are just about to hit a new revolution in the way we do this AI network. So far, these networks are based on data and data alone. There is no understanding, there’s no meaning. But if you look at our brains, we have similar performance and use only a fraction of the energy and we can learn much, much faster, which is why – and probability that we will get to grips with it is very high. So, for example, we spend a lot of effort to develop ontologies, to develop the world model. In our book, I call it The World Avatar, which is basically nothing else but a representation of the world in terms of knowledge in the cyberspace. Now, of course, you could then not just learn on the data as such, but you learn on stuff that is already known. And that, of course, will have an enormous impact. So if you ask me, will the training for networks that can do similar things like GPT-3 be always as expensive as it is now? I don't think so. I'm absolutely certain that within the next few years, there will be significant progress in that respect. The final point, I mean like I’ve already made it, is our brain doesn't use that much energy, which basically tells you there is a lot of room for improvement. Okay, we just haven't quite put our heads around it. I believe, although I cannot

pinpoint a specific area that will improve, I'm sure that because there is so much room for improvement that will happen.

17:35

Jamie: When people talk about the vast sort of potential that's still out there and then you talk about the revolution, it's still going to come in terms of artificial intelligence is that there is still a lot of uncertainty. It isn't always positive. Much of it revolves around fears around uncontrollable forces, right, in terms of what AI can do. And you know, going back to your book, one of the premises is that both AI and climate change pose existential threats to humanity, right? And I see this quote in front of me from your book and you ask this question and I want you to address that too. And you ask what happens if an artificial general intelligence decides that the best way to protect the Earth is to adjust the human population to sustainable numbers? And what if this number is below the current world population? Talk about that and sort of the philosophical arguments that you sort of have within yourself as to the potential and how to manage that in terms of artificial intelligence and its potential to help but also addressing the larger concerns that people may have. Are scientists grappling with this specific to climate change, for example.

18:43

Markus: I personally think this is a very important question, just for the record, okay. I want a happy, happy, happy world for everybody. So whatever we do, we have to make sure that this everybody is catered for. So the question is, what are these dangers and how can we address it? There is actually quite a bit of literature that has already done so, I mean like Nick Bostrom's book on superintelligence is a perfect example of analysing the threats that a superintelligence may pose. Another good book that I've read that I really love was Max Tegmark's *Life 3.0*. I can only recommend this as an amazing treatise of the whole artificial intelligence aspects, and the key word that is important is goal alignment. So we have to make sure that the goals of technology are aligned with our own goals. And this was where the problem starts, because what are our own goals? What is your goal may not be the same as my goal, so how do we cater for this? I have decided that for our work that we start with the Sustainable Development Goals. That means basically the planet has to be sustainable, people should not be in poverty, they should have enough to eat and to drink, we should not have a lot of CO_2, we should have clean water for everybody and so on. If you make sure that the system tries to follow these goals, then my view is how bad can it be? At least at the first approximation, we are sort of safe. There won't be an AI that starts killing people or anything. I think men do that themselves enough. But we have to make sure that the life conditions for everyone, the sort of area that will mean that there is sort of a region, it's not just one point. You could imagine, it would be a bit abstract, but if you think about the Sustainable Development Goals there are 17, each of those have targets that can be quantised to about 10, and then the state of the world can be represented by one point in a 170-dimensional space. Now within that space, you may have a sub-space. If the world was in that sub-space it would be good enough. But whatever happens, this point in that space is moving. Okay, so for example, if there was a massive drought, okay, we didn't have enough water for people and you would come out of the, I would say, comfort zone. So we have to make sure that we constantly keep the world in this comfort zone that is found by the UN Development Goals. This is the way I think about it. Not sure, maybe that was a bit too mathematical in terms of the way I described it. It is a very important question, and what we are trying to do is we not only develop the world model, we also develop a way to classify the world model in terms of these goals, so only then we can do goal alignment. The purpose of our artificial intelligence is actually to make sure that the living conditions for us are good enough to have a happy and fulfilled life.

21:55

Jamie: I'm going to start closing off our conversation and ask really large, even larger questions, maybe, to get a sense of your take on it. It seems that obviously experts in the field will say that AI is not going to be a silver bullet in dealing with climate change. But there will also be optimists, the likes of Bill Gates, for example, who believe that technology will potentially evolve to help overcome such large problems. Where do you stand in the, sort of, the realist versus optimist sort of spectrum? How confident are you in AI's potential as seen in that context? For example, in 2050, if we were to look forward the next 30 years, how much of the gains in our efforts at decarbonisation could actually come from gains in technology and AI? Is it something that should be part of the thinking for people and governments out there?

22:47

Markus: In my opinion, absolutely. But the time period that you have mentioned is so enormous that it's very hard to even think about the technological changes. I have already indicated there may be potential breakthroughs in both the efficiency, but also in the performance of these AI systems. And they just will help us to solve the problems, and you know, they can at the moment be used for maintenance prediction and energy optimisation so basically in the classical way. We don't need to use a machine learning algorithm. You can use a classical algorithm and achieve similar results, maybe not as good as you can do now with AI, but there is more than that because if you look at society at large, it's a complex system. There is a lot of information going back and forth. There is a lot of information loss you see from one people to another. If you just look at how science has been done in the past, how science is done now, if a PhD student found something out they write a little report and then it goes in the library, nobody else knows about it. That's over. Very soon, every finding is a finding that is available to others instantaneously. Imagine the acceleration of the process of finding new things and new solutions to things, and that is also about government. If I look at how governments have to do policy, they are often in the dark and they have a report here, a report there, and they can't really base their opinions on proper facts. It's very hard for them to get it. That with the smart cities and smart states they have completely changed. Not only they will know at any point in time, you know what the state of this, but they can produce proper scenarios, we basically call this parallel worlds. In your system, you can work out what if scenarios and you can implement it right away, very fast. So the time for implementation, time for planning, all that shrinks enormously and that will help us to solve the challenges that we have. It's not just global warming, it's living in peace together. It's making sure that we don't wreck our environment, and I believe that this is doable. I mean, I'm an optimist, I have to say.

25:01

Jamie: It certainly sounds really optimistic. It sounds doable. But as a last question, do you therefore also in your work, have some concern that in using AI, in looking forward to the potential for AI, humans like us may also be tempted to maybe subcontract decisions using an artificial intelligence instead of, you know, I would say, hard human choices, hard human decisions that have to be made separately from what AI may have to deliver.

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Markus: Well, I subcontract decisions to my wife, for example.

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Jamie: [Laughs] That's always the smart thing to do, yes.

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Markus: That was a joke. But what I'm trying to say is this, yes of course, we will subcontract decisions to our own benefit. Every decision has consequences. You have to be aware of what they are and be willing to see them through. You know, if you look at this tale, it's *Time Machine* and you have the Elois and the Warlocks and the Elois are living in this fantasy world, where they don't have to care about anything and sort of slowly develop into vegetables, is that going to happen with humans? I hope not. Even if there was a super intelligence who knew everything that can, you know, it would be not relevant to us because we still enjoy each other's company, our thoughts. Of course, it would be, you know it's like with Wikipedia, you can just look things up, but that doesn't mean that you have fully understood it and you can still think about it. Or you can think about what the system, the superintelligence, says and what it's thinking. So I don't think it'll have an impact on our meaning as a human being. And I think this is very important.

26:43

Jamie: Well, Markus Kraft, thank you very much.

Markus: Thank you for giving me the opportunity to talk to you.

Jamie: And thanks for listening to the Climate Conversations. Stay up to date on CNA's coverage of climate change on cna.asia. You can also find this and other CNA podcasts on our website and on iTunes and Spotify. The team behind this podcast are Crispina Robert, Lin Suling and Erin Low. I'm Jamie Ho again, till next week.