[DAISY THE GREAT](https://daisythegreatband.bandcamp.com/): 00:00 [BUILT MY HOME ON HOLLOW GROUND](https://www.youtube.com/watch?v=z-1sC1lkmKw)

CRAIG: 00:07 Hi, this is [Craig Smith](https://www.nytimes.com/by/craig-s-smith) with a new podcast about artificial intelligence. I'm doing this episode differently. It's about AI and global warming. So, indulge me for a moment.

The opening music for this podcast is a song called Built my Home on Hollow Ground by the band Daisy the Great. They're young and full of promise. They're friends of my oldest boy, and I picked the song because I like it, but also because that line ‘built my home on hollow ground’ says so much about where we are today. When I was in my early twenties I went snorkeling in the Red Sea. It was my first time and it frankly blew my mind. The water was crystal clear. The coral technicolor, the fish polychrome, dazzling in their variety and hue. Decades later, my son learned to scuba dive while we were living in Asia. He was in his early teens and I was delighted by his discovery of the ocean, deeper and more intimate than my own.

CRAIG: 01:06 I loved the photographs from his dives, the barracuda tornadoes, the psychedelic [nudibranchs](https://www.google.com/search?q=nudibranchs&source=lnms&tbm=isch&sa=X&ved=0ahUKEwjYvtrs9-DjAhWQxZ8KHTZaAoUQ_AUIESgB&biw=1309&bih=678). My son will most likely live to see the coral reefs die. Their brilliant colors, bleaching to an ashen gray. His children, if he has any, might not see living coral at all outside an aquarium. No one knows what else will die as the coral disappears.

I worry about climate change, about how my children and grandchildren will survive in a world beyond imagining. Nothing crystallized that concern for me more than John Platt, a computer scientist and polymath, really, and also a father like me. Talking to him made me realize what scientists have been shouting at us for years now; that it is probably already too late to stop the planet from warming an additional two degrees Celsius, the point at which coral reefs are expected to die. But there is a lot we can do to keep it from warming more.

CRAIG: 02:06 Now, predictions can be wrong. Scientific predictions have been wrong before. There's a whole bunch of people who laugh at this stuff, who called people like John alarmists. But what if the predictions aren't wrong? With all the stuff to pay attention to, isn't this problem about as important as it gets? I met John at a machine learning conference, after he spoke at a workshop called ‘[Climate change. How can AI help](https://www.climatechange.ai/ICML2019_workshop.html)?’ It was the first workshop of its kind organized by [David Rolnick](http://www.davidrolnick.com/), [Yoshua, Bengio](https://en.wikipedia.org/wiki/Yoshua_Bengio) and others, and the turnout was huge, standing room only. It was a harrowing yet hopeful few hours. It left me wanting to get involved, somehow.

I'm a journalist and there's certainly a role that journalists can play, but if you are a machine learning engineer, a data scientist, a high school student or postdoc building life in AI, ask yourself what you can do. Listen to John now. Again, I screwed up the audio quality. I'm sorry about that. But listen anyway. He's talking about our shared future, our children's future and the future of mankind.

CRAIG: 03:21 I'd like to talk initially about where you came from, what your upbringing was, what your parents did, you know, that kind of thing, what your education was, how you became focused in the field that you're focused in. And to be honest, I don't even know whether your field is physics or computer science or some other domain - I've heard you speak at machine learning conferences - and then what I really want to cover is pretty much your talk at the workshop; that there are these two related problems, but different problems. One is developing zero carbon energy technology, but it's kind of in sequence. You have to cut the carbon emissions before you hit the 2 Celsius increase that everyone talks about because the zero-carbon energy won't be there in time. Right. Is that right? Do I have that right?

JOHN: 04:22 Yeah, that's, that was one, that was essentially the main message of the talk.

CRAIG: 04:26 Yeah, so maybe start with where you're from and that sort of thing.

JOHN: 04:30 Okay. Well, originally, I grew up in Illinois outside of Chicago, out in the corn fields, and then when I turned 14 my family moved to California and so I went to college, actually in Long Beach. And so, I was an undergraduate chemist and then in 1982 I heard that [John Hopfield](https://en.wikipedia.org/wiki/John_Hopfield) had made this very interesting kind of neural network - it's called a [Hopfield network](https://en.wikipedia.org/wiki/Hopfield_network) - up at Caltech. So, that was sort of exciting to me. So, I decided to go be a grad student at Caltech and they accepted me. So, I went in grad school as computer science.

CRAIG: 05:04 Why did neural nets capture your imagination from the point of view of chemistry?

JOHN: 05:10 Oh, well I've always been kind of a generalist. I still enjoy lots of science fiction. And so, the prospect of, of working on artificial intelligence was just sort of super exciting. I mean, even though, you know, back in the 80s we just had very sort of primitive, simple models. So, things have progressed so far in the last 35 years.

CRAIG: And then the PhD was in?

JOHN: 02:10 Oh it was in computer science, but the PhD had sort of two parts. One was computer graphics. So, I did a bunch of physically based modeling for computer graphics because back then a lot of the, the animations in computer graphics were all sort of designed by hand. So, all the motions were done by hand. And so, my advisor and I and a couple other grad students had this insight that, 'Oh, you want to use physics to kind of run simulations but you want the physics to be controllable.'

JOHN: 05:58 So, we actually sort of made this hybrid kind of physics, which was partially a physics to sort of fill in what the animator didn't specify.

CRAIG: Oh, that's interesting. You know, I've talked to a few people that started through animation and computer graphics, [Sergey Levine](https://www.eye-on.ai/podcast-014) also. That was kind of his initial interest. So, you did your PhD from there, where did you go and how did your career develop?

JOHN: Sure. That was a PhD at Caltech. So, I knew a lot of folks at Caltech, so a bunch of us went and started a company called [Synaptics](https://www.synaptics.com/). They might even be making the touch pad in your, in your notebook computer.

CRAIG: Oh, really?

JOHN: Yeah. And that originally started out as a neural network company. So, that took off. I was also, while I was there, worked on other things like Chinese handwriting recognition. So, that was Synaptics.

JOHN: 06:46 And then a lot of my computer graphics friends were working at Microsoft Research and so I decided to go work at Microsoft Research and come back to machine learning.

S JOHN: So, yeah, at Microsoft Research, probably had my highest cited paper. So, in the late nineties there's a lot of excitement about this model in machine learning call [support vector machines](https://en.wikipedia.org/wiki/Support-vector_machine).

CRAIG: Sure.

JOHN: And so, I came up with one of the algorithms for sort of training them in an efficient way called [sequential minimal optimization](https://en.wikipedia.org/wiki/Sequential_minimal_optimization).

CRAIG: So, you were there until you came to Google or?

JOHN: That's right. So, I was there for about 17 years. I came to Google specifically to work on putting a dent in climate change. That was one of the motivations. So, when I joined Google, they were just starting a project with a partner called, at the time it was called Tri Alpha Energy, but now it's called [TAE](https://tae.com/).

JOHN: 07:36 They have a fusion experiment they've been running and getting, you know, ever closer to breakeven fusion. And so, in the beginning, the project was just myself and another software engineer named [Ted Baltz](https://ai.google/research/people/105016). So, I was the data scientist in the beginning and we've grown that project into a multi-person project where we're doing [Bayesian inference](https://en.wikipedia.org/wiki/Bayesian_inference). So, we're trying to essentially help build a debugger for their plasma so they can, so that their scientists can know what goes on inside of that.

CRAIG: Right. You were showing the graphs that come out of the sensors and then how you were turning that into a visualization of what is going on inside. Yeah. And when did you make the switch to Google?

JOHN: I made the switch at the very beginning of 2015

CRAIG: And was the climate change issue just something that you'd been paying attention to and it finally reached a point where you wanted to do something or …

JOHN: 08:27 That's exactly right. Well, there's a couple of motivations. I have a couple of kids, teenagers now, and so I was very concerned about the future world they were going to grow up in and I wanted to help sort of make that be better. So, that was one strong motivation. Also, I had had some friends, well I used to know, [David McKay](https://en.wikipedia.org/wiki/David_J._C._MacKay), who wrote a very influential book called [Sustainable Energy Without All The Hot Air](https://www.amazon.com/Sustainable-Energy-Without-Hot-Air-ebook/dp/B002LARWGC/ref=sr_1_1?keywords=Sustainable+Energy%E2%80%94Without+the+Hot+Air&qid=1564593134&s=gateway&sr=8-1). And I knew him because he also went to grad school at Caltech underneath John Hopfield. I also had a friend named [Tim Allen](https://patents.google.com/?inventor=Timothy+P.+Allen) who was my counterpart at Synaptics. He was the director of engineering and I was the director of research and he started getting excited by renewable energy and came to Google to work on it. But sadly, he passed away in 2011 I think. And so, I sort of felt a little bit like, I was the one to carry on his work.

MUSIC: 09:24 MUSIC

CRAIG: 09:24 So, initially was it just general study or were you focused on a particular problem and was it always in applying machine learning or was it broader than that?

JOHN: 09:35 It was broader than that. Although I guess, you know, Google's very good at machine learning. It has a large amount of computing and it's my background. So, I was looking to see if there was something with machine learning. It took me a while - I mean the whole sort of geophysical and energy and economic systems, they all interact and they're all very complicated - so it actually took me quite a while. It probably took me a year to come, to come up to speed while I was sort of starting to work on this fusion project. So, yeah, what, originally, I thought is that we would need to go for a strong energy miracle. And what I mean by strong energy miracle, it's something where you can - so I mean, you know, Bill Gates talks about [energy miracles](https://www.theatlantic.com/magazine/archive/2015/11/we-need-an-energy-miracle/407881/) in general and so I sort of separate those into two different regimes.

JOHN: 10:18 There's something I call weak energy miracle. So, it's like some zero-carbon energy source that's cheaper than new coal plants, new natural gas plants for electricity. But that might not be enough because we really need to dramatically reduce carbon very soon. So, you want a zero-carbon energy source, ideally, that is cheaper than old fossil fuel plants. And that's very difficult. Things like fusion might eventually become that, but it might take a number of decades before fusion becomes cheap enough and ubiquitous enough if we can get it to all work now. So, a lot of these hoped for technology breakthroughs are, might kick in after 2040 or 2050, might be a number of decades just to develop the technology to bring it to production and to make enough plants to actually make a difference. So, we should still do that. That's a great thing to do. It would bring prosperity to the world, that we really want sort of ubiquitous, very inexpensive zero-carbon energy.

JOHN: 11:14 I think that's where we'll end up at the end of this century, but we have a much more pressing issue now. Right now. Start decreasing carbon just from the present fossil fuel infrastructure.

If you just let it continue throughout the lifespan of the infrastructure, we're still, we're committed to another 660, roughly, gigatons or billion tons of CO2. That’s essentially enough to blow us past 1.5 Celsius and almost to 2 Celsius. If you count things that are currently under construction or planned, then we will. We essentially have to stop building fossil fuel infrastructure now, like today, to get to 2 Celsius. This is assuming that we don't take any carbon dioxide out of the air in the second half of the century, which many people are hoping that we'll do. But if we don't, if we can't do that, if that's not economically effective, we have to stop now in order to even hit 2 Celsius. So, it's really very, very urgent. We have no more time to waffle or, or, or think about it. We're driving very, very close to a cliff of, of dangerous climate change.

MUSIC MUSIC

CRAIG: 12:31 For people that aren't familiar with the benchmarks, above 2 degrees is the melting of the ice sheet and the rising of the seas. I mean what, what are the affects that …

JOHN: In general, there is no known absolute threshold. Like if you're at 2 Celsius, you're okay. And if you're a 2.01 Celsius, everything is terrible. 2 Celsius, because of the [Paris Agreement](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement), is the general sort of threshold for what's considered dangerous climate change. And if you go and look at the [IPCC reports](https://www.ipcc.ch/reports/), various things happen. You know, for example, a very concrete thing is they're expecting 99% of all coral reefs to die at 2 Celsius. At 2.5 Celsius, you start to get sort of food yield impact because essentially things just get too hot or too dry or too wet. Many of the ecosystems, this happens very early, much like the coral reefs start to, you know, get very strongly affected, even at 2 Celsius.

JOHN: 13:24 What I've understood from just talking to people, I think people are getting very alarmed when, when the IPCC came out with this report last year called the [SR-15 report](https://www.ipcc.ch/sr15/) or Sr15 report, which is strongly trying to encourage people, well you know, 2 Celsius, this is too high. We really need to be at 1.5 Celsius. The trouble is, like I said, I think if we have a sharp right turn now we'll hit 2 Celsius, unless we can figure out how to get CO2 out of the atmosphere in the second half.

CRAIG: Let's back up to energy need. And the growth of energy consumption in historic times. It is increasing roughly 2% a year. And there's no reason to think that that demand wouldn't continue at 2% a year until the end of the century.

JOHN: 14:20 That's right. In fact, if anything, if we could solve this zero-carbon thing, it's a good thing to increase energy because I would love to see the entire world get a developed economy. And as economies develop, the pattern in the past has been that they consume more energy because their, their GDPs grow very quickly. So, I would like to be in a world where in 2100, when the UN projects that there's 11.2 billion people, that all of them use as much energy as people in the United States do. Except for carbon, that would be a wonderful world. Everyone will be prosperous. It'll be, it'll be a wonderful world. I would love, that's part of the reason why I work on fusion. I want to reach that world, but we can’t reach that world with fossil fuel. We just can't, even though people worry about running out of fossil fuel, there's more than enough fossil fuel in the ground to completely bake the climate. That is not the limiting factor. If it weren't for climate change and CO2, fossil fuels are wonderful. They're portable, they're inexpensive. Coal has a lot of pollution, but things like natural gas, uh, it's just, it's the, it's the greenhouse gases that are the problem.

CRAIG: 15:14 If we were to stop producing or building new fossil fuel plants today, fossil fuel powered electric generation plants today, is the renewable technology available or sophisticated enough to fill the gap?

JOHN: 15:32 Sort of. So, renewable energy has certainly gotten very inexpensive. And other than it taking a fair amount of land area, especially with wind power - although you can use the land for other things - there's sort of a problem in that renewable energy, sun, solar and wind, it, sort of, generates when it wants to, not when you want it to. And so, there's sort of something - we call it the calm, dark problem. Like if it's very cloudy and there's no wind, you don't want to shut your electrical grid down. So, it turns out that people have a lot of hope about electrochemical storage, essentially, huge, sort of, some sort of batteries hooked up to the grid. At least according to my economic models, it's hard to imagine the storage getting cheap enough where that will be cost effective. Now it really is a choice, right? If people are willing to have sort of primary energy cost much more than it does today in return for having a good climate, then it would work.

JOHN: 16:34 You could, you could bridge the gap with renewables and storage. But the trouble is, it's so critical in so many different places - everything uses energy - that there's a strong impetus to not want to increase the cost of energy. Right now, without any kind of carbon pressure, there's no impetus to go to that more expensive solution. Um, so technically it is feasible, but it would just be much more expensive. And so then, we have to just decide as a civilization about whether we want to do that. There's also questions of land use and things that we'd have to put, you know, wind farms pretty much everywhere in the Midwest. Things like that.

CRAIG: 17:17 And the expense issue then separates the world into those who can afford energy and those who can't.

JOHN: 17:24 Exactly. Right. It would, and again, that sort of contradicts my hope, which is, I want inexpensive energy for everyone to become sort of well off and it would be wonderful and I think we will get things like fusion or other inexpensive sources of energy in the second half of the century. I think we can displace fossil fuels. But in the meanwhile, we have to do something with renewables and try to figure out how can we make them less expensive or more flexible. Things like that.

MUSIC: 18:01 MUSIC

JOHN: 18:01 The last time I heard you talk, you talked about having standby generation to kick in when solar or wind dips. You did not talk about nuclear. Could nuclear fill that gap until there are zero or other safer zero-carbon technologies available?

JOHN: 14:37 It can. For existing nuclear fission - to be precise, fission plants - it's very expensive to build. I believe the last fission plant attempted to be built, I think in Georgia, in the United States, [caused a company to go bankrupt](https://centurysolarsystem.com/westinghouse-bankruptcy-nuclear-train-wrecks-for-georgia-and-south-carolina/). But, certainly leaving existing fission plants operating or extending their lifetime is actually going to be rather important for zero carbon. I mean it's, it's, it's still controversial, but I think the consensus is starting to swing as, no, we should, we should leave the existing fission plants operating because it makes it, when you turn them off, it makes a big hole, which you then have to fill with something that produces carbon, which is just bad.

CRAIG: 19:02 But in terms of building more.

JOHN: It's not very economic to take the existing sort of old, I mean the, the, the designs, the technology of fission plants have been largely unchanged for decades. There's hope that there's, I mean there's a, uh, a bunch of nuclear startups who think that they have newer, safer, less expensive fission plants that they can build, but they're still, it's still very early in the technology cycle. It might, again, it might be possible that in the second half of the century, we may have much safer and much less expensive fission plants, but it's not, sort of, in hand right now.

CRAIG: And there really, as you pointed out, there isn't a lot of time. All this stuff has to come online, these solutions, in a matter of decades.

JOHN: Or a matter of years. Things have to be shovel ready, so renewables right now are there.

JOHN: 20:01 They're available. We should at least, there's no reason to not at least build them up to take half of the electricity. But electricity is not everything. Essentially, electricity's maybe only quarter of the greenhouse gases. Land use is also very important. Transportation. Now you can electrify some transportation. I have a plugin hybrid myself. But, for example, industrial heat is very difficult to replace because you're just burning fuel, which is, there's no, there's nothing else that - you don't have a plant. I mean, you're just burning fuel to get heat.

CRAIG: Well again, nuclear could ...

JOHN: No, It's very hard to compete because nuclear power, I mean, yes, nuclear power does produce heat, but you wouldn't want to have a nuclear plant right next to your cement plant.

JOHN: 20:52 So, generally you want to transport, whereas a natural gas pipe, if you have a flame at the end, is a very efficient, inexpensive way to distribute it. It's going to be very difficult to displace industrial heat. And land use, I mean, it's possible that we can change the way agriculture works, but we have to change it all around the globe to make sure that we don't do deforestation, that agriculture actually is a carbon sink as opposed to a source. So, that's part of the problem, why climate change is such a difficult problem, is there's so many sources of greenhouse gases. So, even if we fix electricity and we electrify cars - very hard to electrify planes - a lot of things that are just very stubborn. We'd have to make things very inexpensive. There has to be some motivation, right? Either people want to do it because there's a general agreement that we have to really make our sharp right turn to, to save the climate. Or the new technologies just have to be much cheaper than, than the existing technologies. Then people will just naturally do it because they're motivated from the profit motive.

MUSIC 21:59 MUSIC

CRAIG: 21:59 However, you said you were optimistic last time I heard you talk and I, I kind of wondered why. Because quite frankly, you know, even with the Paris accord, the idea of getting countries to decommission existing fossil fuel powered electricity plants alone is difficult.

JOHN: 22:24 Why am I optimistic? I am .. I refused to be paralyzed. Right? This is an important problem. I think people know it's an important problem. Over the last two years I've been, you know, just talking to people and there, and sort of the alarm level is starting to go up. I think people are getting out of the complacency. You know, in the second half of the century, I mean, I think there's a lot of things that we can be doing and technology advances. So, I think we will avoid the utterly catastrophic climate change of both like 3 Celsius. And so, we have to really keep everything below three. I mean 3 is not a good thing. So, now I think it's going to be a knife fight for every 10th of a degree Celsius between 2 and 3. So, I'm optimistic that we can avoid, you know, existential risk at like 4 Celsius that I think there's enough that we can do to keep it below 3. So, now let's try to make the world be as good of a place as we can by sort of fighting for every 10th of a degree below 3. So, that's why I'm sort of, I don't know if that's an optimism or if it's just a just sort of a determination.

CRAIG: 23:32 Yeah, but that's assuming that we blow past 2 Celsius.

JOHN: I think 2 is the floor.

CRAIG: The floor, not the ceiling.

JOHN: 19:55 I think. I think - not the ceiling, I know everyone wants 1.5 [Celsius degree increase]. There is one way to make us go below 2 and, in fact, if you look at the IPCC decarbonization paths, they all assume, because of just the constraints of geophysics, that after 2050 we're going to have what they call negative carbon emissions. And, typically, the IPCC assumes that we're going to use something called [BECCS](https://en.wikipedia.org/wiki/Bio-energy_with_carbon_capture_and_storage) - bioenergy and carbon capture and sequestration. So, what you do is you grow some sort of cellulose, some sort of plants on your land, maybe not the good land, but still some land somewhere. Then you go and you burn it and you get electricity out and then you take the flue gas that's in the chimney and you capture the carbon dioxide and you shove it underground, you compress it and shove it underground.

JOHN: 24:26 Yes all of those are actually, well carbon capture is, is a nascent technology. There are technology advances in carbon capture that look promising. It's not, you know, there are carbon, pilot carbon capture plants, that are rather expensive, that might work. I'm most concerned about is that, that it uses up a lot of land. That agricultural land is actually a precious commodity. Here's an interesting fact that I like to quote. The number of terawatts of power that our crop lands fix, in other words they convert, we grow crops in order to turn sunlight into sugar, fundamentally. That is about, roughly, 5 terawatts or 5 trillion watts of power. The amount, depends on the year, I guess. The amount of fossil fuel, primary energy burn, I think when I last checked was about 18 terawatts. So, our energy system is larger than our biosphere, at least the biosphere we control.

JOHN: 25:23 I mean there's lots of phytoplankton and things in the ocean. But, but in terms of the crop land that we make, we're essentially using, we’re, the whole fossil fuel is based on borrowing sunlight that happened tens of millions of years ago, borrowing what the plants did, and that's actually larger now than what the plants are giving us now by a factor of three a year or more. So, yeah, hoping to get a lot of bioenergy. I mean, you might be use it for aviation fuel, but it's not going to be enough. There was [a paper](https://keith.seas.harvard.edu/files/tkg/files/keith_et_al._-_2018_-_a_process_for_capturing_co2_from_the_atmosphere.pdf) by [David Keith](https://en.wikipedia.org/wiki/David_Keith_(scientist)) at, at Harvard, which proposed that a direct air capture plant can operate at about a hundred dollars a ton of CO2. That's a lot lower than I expected, although that is still quite a lot. Just to give you a sense, right? You need - every degree Celsius I think is 2000 gigatons of CO2 so that's $200 trillion to suck the CO2 out. Far better to either put carbon capture now, on our fossil plants now, than hoping that we can blow it out in the air and then pull it back in.

CRAIG: 26:30 Yeah, that's right. I don't quite understand this idea about burying the carbon.

JOHN: Oh, that general idea is called carbon capture and sequestration. It's just like in coal plants, you have scrubbers that scrub out the sulfur dioxide or the sulfur oxides and the nitrogen oxides? You can scrub out the carbon oxides, carbon dioxide. It's expensive and you have to compress it and then you have to figure out what to do with it. The amount of carbon dioxide we produce is very large. You could try to convert it into fuel or do something with it, but it turns out that requires a lot of energy. The cheapest and easiest thing to do is to compress it and shove it underground in like old oil, oil and gas reservoirs or under, in, there are these saline reservoirs. You can put thousands of gigatons underground. Underground is a very large place. So, that's how carbon capture works.

CRAIG: 27:17 Yeah. There's this other problem as the, as the climate warms, the permafrost is thawing and that's releasing tremendous amounts of carbon into the atmosphere.

JOHN: Yes. It seems like the tundra is becoming a carbon source instead of a carbon sink. Because apparently like peat would accumulate and sort of hide carbon. Yes. That's why it's really important. Best to stay under 2 if we can. I don't know if that's still available to us, but every 10th of a degree you go up, you raise the risk - it's very hard to quantify - of, of some sort of positive feedback cycle. Like I don't know if anyone knows for sure. In fact, even those with high confidence, whether 4 Celsius is a stable climate or whether there'll be some feedback cycle, that'll take you up to 6. And to give you a sense, 4 Celsius is the gap, is the gap between the bottom of the ice age and today's climate.

JOHN: 28:22 So, it's not like you think, oh what, you know, 4 Celsius, that's what that's, you know, 7 degrees Fahrenheit, backhand. Who cares about that? No, that's a huge climate change.

CRAIG: Yeah. Even with the warming climate today, people are using more air conditioning than they did before, so they're drawing more electricity, which requires more burning of fossil fuels.

JOHN: There are possible positive feedback loops in between the economy and the geophysics that are exactly like that because one of the concerns is that even by mid-century there will be places, big cities, like in India where there might be days where it's just like, you know, fatal to go outside - the combination of heat and humidity is just too high, so that's terrible. So, yes, you will use more air conditioning to try to, you know, help people, which is a good thing to do and that will, we need more energy to operate that.

JOHN: 29:14 You're absolutely right. [Jevons paradox](https://en.wikipedia.org/wiki/Jevons_paradox) is an observation made by a British economist back in the 19th century talking about coal. Was that, was that his, I guess his prediction, or perhaps it was about, it was actually a post-[Watt](https://en.wikipedia.org/wiki/Watt_steam_engine) observation, which was as steam engines, which use coal, got more efficient, you would think, oh, the amount of coal use will go down because steam engines are the big, at the time, were the big use of coal, so what do you do? But it turns out that it actually made the coal use go up because then steam engine, because everything became cheaper, so now people wanted to use it in more places and people got wealthier because the steam engines were making lots of products. So, there's a feed, there's something called direct, like a direct effect, which is okay if you use, if something gets cheaper, people tend to use more of it.

JOHN: 30:04 But that never gives you a feedback of more than one. Through the economy, you can get - some people say that you may, you save energy, now you're making people wealthier, wealthier people and wealthier economies produce more, which then through the feedback loop for the economy actually uses more energy. Now it's controversial. Economists come on different sides of what the coefficient of, of, of feedback is. If it's a big one. But, look, any research that makes - for, for like using machine learning to make systems more efficient and use less energy, that's a good thing. We should do that anyway because again, spending less money on energy makes people better off. That's a bonus. But it might not make as much progress towards fixing climate change as you think. And it might make zero progress or a little bit or a little negative progress.

CRAIG: 30:52 On fusion, let's imagine that they solve the engineering problem and we suddenly have limitless zero-carbon energy. Is that enough to avoid the 2-degree threshold, if nothing else changes; the industrial heat, use of fossil fuels or, or the agricultural land use?

JOHN: 31:16 Well, it depends how inexpensive. It depends. We don't know. It's still very early. We don't know how inexpensive fusion will be because it depends on this [quantity called Q](https://en.wikipedia.org/wiki/Fusion_energy_gain_factor), which is the ratio of how much energy you get out for how much energy you have to put in. If that's very high, then it will be very inexpensive. But if it's not high, then it won't be. So, yes, we still have to worry about land use. You're not going to have fusion powered aircraft, so it'll help a lot, but it won't necessarily.

CRAIG: It's not the answer.

JOHN: It'll be a great thing and it will make the world a prosperous place if we can crack this problem. I think it's still a wonderful problem to work on. Like you said, there's no silver bullet. Not even fusion is a silver bullet.

MUSIC: 32:04 MUSIC

CRAIG: 32:05 Right. The point of this conversation is to talk through the podcast to machine learning engineers and researchers and people interested in the field. There are many, many different ways that machine learning can be applied to tackle this problem. As you said, it's not just coming up with zero-carbon energy solutions or containing fusion. It could be mapping the methane emissions from the wetlands across the world and just understanding how much methane is being released during what periods and once you have that data, maybe then being able to come up with some sort of mitigation strategy. Can you sort of hit the high notes of where machine learning can have an impact?

JOHN: Well, I was helping out. We wrote [our paper](https://arxiv.org/abs/1906.05433) that was in parallel to the workshop that you went to that, that I spoke at, which is on [arxiv.org](http://arxiv.org/) about how AI ...

CRAIG: I haven't read it yet.

JOHN: 33:08 Okay. Well so that was a very long paper with, I forget, 700 references. It was a very, very long paper and I want to point out a lot of the authors spent, a lot of time. I was, I was helping them with a little bit of editing, but – so, that's a lot of work by a lot of these postdocs and grad students. So, we, what I would do is, is recommend that machine learning people like, look at that paper and see if something inspires them. I think that the paper is not meant to be exhaustive, that hopefully it's more inspirational or people will see sort of, kind of, patterns.

JOHN: So, you're right that a lot of what machine learning can do is, is around measurement. So, like [Andrew](https://en.wikipedia.org/wiki/Andrew_Ng) was talking about maybe using, finding methane. There was [another interesting talk](https://slideslive.com/38917841/truck-traffic-monitoring-with-satellite-images) at that conference by one of the coauthors of the paper where she was saying, you know, we just don't know where the trucks are, so can we use machine learning to kind of look where the trucks are?

JOHN: 34:00 So, I think machine learning will be super helpful just in terms of having smart measurements, like just even trying to understand this very, very complicated sort of geophysics plus economic system. We, it's just very hard to measure it across the - because the whole world has to, that has to work. There's some amount of hope that we can build a more intelligent electrical grid. There's some difficult optimization problems in terms of how do you dispatch, where do you send electricity and there's some amount of hope about, well maybe we can, if we can predict, because this the, as I was saying, the renewables have a, fluctuate up and down. The better you can predict what they're going to be doing in a day, hopefully the less fossil fuel, less fossil fuel capacity you need to do to kind of cover the gaps. That will help.

CRAIG: What about in, in agriculture?

JOHN: 34:54 Oh yes, yes. In fact, the a, that's right. It could be that because land use is such a large fraction of sort of greenhouse gas emission. Can we use machine learning? You know there is, at least in the United States, agriculture is this very sort of mechanized high-tech thing. I don't know if you've visited farms, it's these, these amazing combines with software and sensors and all sorts of amazing things.

Can we use machine learning to kind of help change how we sort of optimally plant things and maybe especially if the climate changes, we need to figure out like how do we sort of grow these plants so that we don't lose yield against the, the uh, the climate. Another way is, or can we figure out like is there ways to breed or genetically change some of these plants to make them more, more robust or to make them have more, more calories to generate food.

JOHN: 35:50 Another way machine learning can help is alerting. Here at Google there's a team that's working on flood prediction. So, there's a lot of machine learning that goes through there both to try to understand, you know, the actual floodplain, which changes and so you need sensors these sort of like satellite scans to kind of figure out how that floodplain changes and also just trying to predict, you know, how much water is coming through the system. So, there's a lot of sort of machine learning there. And so there could be other kind of alerting things that again, using, we should be, and that's more for adaptation. I think machine learning could also be very helpful, not just for mitigation, trying to prevent climate change, but, but trying to help, you know, can we make 2.5 Celsius be much less dangerous? I mean it's going to be a problem.

JOHN: 36:35 Like I said, even if all the coral reefs die, that's a serious blow to the ecosystem of the, the ocean. But you know, one thing there was some, a lot of people are interested in using machine learning to, they do wildlife monitoring. So, maybe we can try to save some of these species that are having this giant hammer blow of climate change. Can we, can we help you know, rescue them, move them or preserve them.

So, I think there's a lot of things that that can be done so that your, your listeners might want to [read this long paper](https://arxiv.org/abs/1906.05433) and don't necessarily have to do the things in there. Hopefully they can. That's just a start to sort of like what can they do to help they, hopefully it's more, I mean it's, you can work on those things or maybe can inspire you to do other things. Because I think that, I think it's not, there's no silver bullet that will help. This Is a very, very, very complicated problem. And so there won't be a silver bullet. But maybe if we all work on different parts we can make progress.

MUSIC: 37:40 MUSIC

CRAIG: 37:40 Yeah. Artificial intelligence in the popular mind has developed a very negative narrative. I think that this theme of using machine learning to address both in mitigation and adaptation of climate change is a way to turn that narrative around. Because you know, everyone thinks of AI as robots that are going to enslave humanity, but in fact machine learning is probably our best hope at surviving climate change. Is that overstating it do you think?

JOHN: 38:19 I would state it differently, which is artificial intelligence. I mean it's, it's, it's almost a misleading term to me. The reason why I like sort of 'machine learning' is because it enhances human capabilities. A lot of it is autonomous in terms of it runs much faster than humans. So, for example, it can filter spam mail. You don't want to have a person read every email. So, but what I'm excited by is how AI and ML actually enhances human capability. So, I think there's a tremendous good where we can try to solve some of these hard problems by essentially applying these machines to essentially help people become more like themselves. So, instead of, there was a [contrast between artificial AI and IA](https://www.weforum.org/agenda/2017/01/forget-ai-real-revolution-ia/), artificial intelligence and intelligence amplification. That was a term maybe not so popular any more, but yeah, I still think that's true that I think the whole point of having machine learning is to make us collectively more intelligent.

JOHN: 39:18 I think by making us collectively more intelligent and wiser then we'll solve, will solve these problems. I think what it is, is you need to get people organized in some way. There has to be some sort of organizational principle. Capitalism and profit is one way to organize people, which is why I've been looking for a strong energy miracle because if we could figure out how to make zero-carbon energy just be much cheaper than fossil fuels, then they will just naturally be displaced. So, you can think of that as an organizing principle to kind of help us all, but that might not be possible or it might be too slow. It's just a matter of making a decision, sort of collectively, what, sort of, how collectively can we act and machine learning can't do that for us, but it could help provide new possibilities for action and it can, you know, make things less expensive so that it's easier to make those decisions. But it can't replace us making collective decisions.

CRAIG: 40:21 That’s it for this week’s podcast. I want to thank John for his time and Godspeed in his efforts. For those of you who want to go into greater depth about the things we talked about today, you can find a transcript of this show in the program notes. I've included links to the paper that John referenced and to videos of the workshop, Climate Change; How can AI Help? Let us know whether you find the podcast interesting or useful and whether you have any suggestions about how we can improve. The singularity may not be near, but AI is about to change your world. So, let's pay attention.