

A Four-Zero Climate Solution

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Announcer: This is Climate One, changing the conversation about energy, the economy and the environment.

On today's program - hard truths and hard numbers.

Arun Majumdar: *Because if you look at 1.5 degrees, it's about 13 years. If you look at 2 degrees, which is what we agreed upon in Paris, it's 20 years. And after that by the way, it's zero.*

Announcer: Meaning: zero time left to solve our planet's climate problem. But there are ways to turn that zero into a plus - if we act fast enough.

Kate Gordon: *We need to start thinking about carbon removal now. We can't wait for the second half of the century to start doing the research and development and getting this to scale and figuring out the technology and stopping deforestation because these things have got to be part of the current solution.*

Announcer: The four-zero climate solution. Up next on Climate One.

Announcer: Can getting down to zero save an overheated planet?

Climate One conversations - with oil companies and environmentalists, Republicans and Democrats - are recorded before a live audience, and hosted by Greg Dalton.

If you want to keep the earth's temperature increase below two percent, Arun Majumdar has some numbers for you:

Arun Majumdar: *We have a budget of around 800 gigatons of CO2. We are emitting about 40 gigatons of CO2 per year roughly globally. So you do the math. If the emissions are flat we have about 20 years and after that it has to be zero, okay. So that's the equation we have to solve.*

Announcer: On today's program we'll talk about how to solve that equation. But don't worry, there won't be a test. And the only number you have to remember is zero:

A zero emissions electric grid, zero emission transportation, zero emission buildings and zero waste manufacturing. Getting to zero in those four areas could be the climate solution.

But can we get everyone working on the same page?

Kate Gordon: *While the problem is inherently global the impacts are extraordinarily local. The impact here in California right now is wildfires; it will be mudslides next year, probably whereas the impact in Houston is something else, whereas the impact in the northwest is ocean acidification. So it's very, very local. So what it's gonna take, it's gonna take shifting this to become a global economic crisis,*

Announcer: Today on Climate One, Greg Dalton welcomes three experts to talk about getting down to zero - together.

Kate Gordon is a Fellow at the Columbia University Center on Global Energy Policy. Hal Harvey is CEO of Energy Innovation and the author of *Designing Climate Solutions: A Policy Guide for Low-Carbon Energy*. And Arun Majumdar is Co-Director of the Precourt Institute for Energy at Stanford. He was formerly at the U.S. Department of Energy, where he was founding director of the ARPA-E research program.

Here's Greg Dalton.

Greg Dalton: Let's begin with the elections are fresh of mind, a lot of energy things, Hal Harvey, you know, there was seem to be a lot of the initiatives went down at the states, the voters when asked about, you know, energy, voted no in a lot of cases. But the candidates with carrying clean energy messages seem to do much better so parse that for us.

Hal Harvey: Well, luckily most energy policies are state-by-state in America. Roughly half the carbon in the economy runs through monopoly pipes and wires and therefore the utilities commissions get to decide whether those feeds are green or brown. And we have a lot of green governors elected and a lot of pledges. I think half a dozen pledges to go to 100% renewable energy on the grid by 2040, 2045 and 2050.

So I would say it was a very strong course election --

Greg Dalton: Of course when you're running for election that's, you know, kind of cheap and easy, right?

Hal Harvey: Well, it's getting cheaper and easier to do the right thing that's the other great news. So solar prices have dropped to 80% in the last decade. Wind is down by more than half; offshore wind is catching up, batteries by 80%. So it's no longer a choice, in fact, it would never was a choice between doing the economical thing and doing the right thing. But now you have to consciously decide to pay more if you wish to continue to pollute.

Greg Dalton: For new generation. Kate Gordon, your take on this, we did see Jared Polis in Colorado, J.B. Pritzker in Illinois, Gretchen Whitmer in Michigan, Tim Walz, Wisconsin. A lot of, you know, governors saying they want to go support Paris go to green energy. But when voters were asked do they wanna pay more, they went, nah.

Kate Gordon: Yeah, I think I'm excited about the governors; I'm from Wisconsin so that was a really big win for me personally. I think what we saw in Washington State for instance, where we saw a second carbon tax go down again, was really less about voters not thinking this stuff is important, and more about a very real urban, rural split in this country. And the thing about Washington State that people often forget because we think of Seattle as being Washington State, King County, is one part of Washington State. There's a huge amount to the east of King County and when you look at the returns on that initiative it needed to get more than 60% in King County and

the neighboring counties. It didn't make it for a variety of reasons but it got almost maybe 10% or less in many of the eastern counties. And so I think that's actually an important lesson as we go forward on these issues that as you're looking at this stuff state-by-state not just district by district, the districts that elect clean energy champions are often urban districts frankly, or they are places where the industry is very clearly already established.

So you have a big wind farm that's employed a bunch of people or you have, you know, some kind of other industrial plant or some kind of other clean energy, a data center that's running on renewables, whatever. In a lot of states, there's still a really strong kind of economic engine that's based on extraction or it's just not this hasn't come to those places. And I think we have to do much better job of making an economic development case around energy and not just an environmental case.

Greg Dalton: Arun Majumdar, your take on, you know, you've seen budget, you've seen bipartisan support for clean energy, ARPA-E, you know, I think there was some, Trump wanted to smash some budgets and Republicans lifted them back up. Your take on the outlook after this election.

Arun Majumdar: Well I mean I just look at California for example. I mean I think we are all in the middle of, you know, just a disaster situation with all the forest fires and the impact on the environment. And this is, you know, due to the extreme weather that we've had, the droughts that we've had, and this is the impact of climate change which is we're seeing it happen and we're all getting affected by that. And I think at least in California if energy and environment is not taken into account, I think it's a risk that I don't think people will allow that to happen. And we saw that in Southern California and Orange County, etc. that, you know, that that is right in front and center.

So I think this is affecting people's lives and when extreme temperatures, I know people talk about 1° or 1.2° of temperature rise above since the beginning of the industrial revolution, that's the wrong message frankly, it's not the average it is the tail of the distribution. And the distribution, the tail is reaching 4 to 5 Stein to a standard deviation that was formerly had. And those that tail, and there's a very important scientific term for this, the tail is wagging the dog.

[Laughter]

And when the tail is wagging the dog we are seeing that happen right now. And I think if politicians don't pay attention, I don't care whether it's Republican or Democrats, if the people are affected by it and the politicians are not paying attention to that, they're not listening. And I think that's what we're going to see.

Greg Dalton: But Kate Gordon, the climate connections not being made in the media. If you ask a lot of people, are these fires related to climate, a lot of them say, maybe, you know, that connection. And then these episodes, these severe traumas come and they go and then we forget. Harvey came, you know, Houston's had 500-year floods and then we are resilient, you know, we move on and we forget, so they don't last.

Kate Gordon: Well, Houston had three 500-year floods within five years. It actually drives me a little bit crazy that the media is not putting more of an emphasis on climate change with the fires. I absolutely understand you cannot attribute specific fires to climate change, but we absolutely know and, you know, we've seen the modeling on this. That there will be more frequent fire seasons and they'll be more severe just as there'll be more frequent mudslides seasons that's gonna be the other half of the coin here. In California it's gonna be mudslides and fires and we need to be prepared as a state to go forward on that. One thing, just in response to Arun, you know, I think that it's absolutely true that in places where these impacts are being felt there's more public awareness but

we did just see Representative Carlos Curbelo get voted out in Florida. This is a Republican representative who started the bipartisan climate caucus in the house and put forward a carbon tax proposal that was actually very thoughtful and very, you know, well regarded and was brought down by environmental organizations that didn't want a Republican in that seat. I also think we need to be looking carefully at that because that kind of situation we need to be supporting champions of action who are willing to put their necks out in difficult districts. And that was one that I think we went the wrong, the environmental community went the wrong way on.

Greg Dalton: Hal Harvey, we're talking about zero emission electric grid, in fact there's some suggestion that the fires in California were started by perhaps a downed utility line. Zero emission electric grid that sounds possible in California, is that something that can spread nationwide? Voters again, pushed back on that in Arizona and some other places.

Hal Harvey: So I mentioned earlier, the dramatic price drops in both solar and wind energy and the ones that are now occurring with offshore wind which is a completely different paradigm. Different times of day that the wind blows and different strengths. What these cost reductions have done have made it possible to radically accelerate the transition to a zero carbon grid. And people automatically think that if you go to variable sources like wind and sunshine you need huge batteries to carry you through the night or through a long cold winter week in North Dakota. It turns out there are half-dozen ways to deal with the variability problem.

The first is geography. The winds in California and the winds in Wyoming are not correlated; they happen in different times. So when you hook them together with good transmission lines which exist in many parts of the country already, they smooth each other out. Same thing goes with solar. If you have solar in Nevada and solar in California they're gonna have peaks at different times and they smooth each other out. You can continue right across the Sun Belt there. So that's just one example of ways to balance the system.

Let me offer one more which is regional variations of demand. So, Seattle and San Diego never have the same peak demand and they have different energy supplies. Copper wire is magic between those two because a Bonneville Power Administration becomes the battery for San Diego. And San Diego can shoot excess energy to the data centers in the Microsoft Amazon zone when it's needed. The point here is we can move to a zero carbon grid much more quickly and at net savings than anyone thought possible even five or 10 years ago and there are a number of states that are well on the way.

Greg Dalton: Kate Gordon, you spent some time in Wyoming and don't necessarily want their grid connected to California. So there's a lot of politics in the electrical grid that is, you know, Texas has their own grid, thank you very much not connected to anyone else. So the politics of the grid are fierce.

Kate Gordon: You know it's funny I spend a lot, I was just in Wyoming two weeks ago and I was in Idaho two weeks before that. And I will actually tell you in Idaho they do want their grid connected to California because they have an enormous amount of hydropower it's very cheap and they wanna sell it to us. They see California as a big market full of consumers that just voted in a hundred percent clean energy bill that they can then supply through hydro through potentially negative emissions from their forest sector. I mean it's very interesting it's sort of a turn on what you'd think because you go to Idaho and you're from California and I'm used to people not listening to me because I'm from California. But now all of a sudden there's this different story which is, oh these guys are really close to us we have access to their market and they want our stuff.

And I think that's interesting and we may see some of that in Wyoming too. Wyoming is a little more

challenging because 70% of Wyoming state economy comes from extractive industries it's all coal and now coal going down but gas going up. So they're in a little bit of a different position they're worried about getting connected to a grid that has a 100% energy standard. But I still think there's a message out there that we could become, I think the Western grid conversation could be opened up by this idea of California really creating markets for some of the stuff.

Hal Harvey: The biggest wind farm in America is being built in Wyoming today.

Kate Gordon: They like wind a lot.

Hal Harvey: So one other thing to keep in mind is two thirds of all renewable energy built in America has been built in so-called red states. So this is not an R versus D thing, this is smart versus not so smart thing.

Greg Dalton: And Arun Majumdar, one of the things here is to talk about electrifying everything which would then grow the grid. So tell us about the path for electric adoption, electric vehicles, basically electricity is cleaner, cheaper than burning fossil fuel.

Arun Majumdar: So the issue about electric vehicles is really about the cost of batteries. And if you look at over the last decade R&D in materials that goes to the batteries has brought down the cost of the batteries by a factor of 5 to 6 which no one had predicted 10 years ago. I was in the department of energy we were investing, we were hoping and it happened faster than we thought. If you look at now it's about, you know, about \$150 to \$200 a kilowatt hour of a battery. In the next 5 to 7 years we anticipate based on the innovations that are going on again in the materials and the packaging and all that, it'll come down to \$100 a kilowatt hour. What does that mean? At \$100 a kilowatt hour, in the next 5 to 7 years the electric vehicles would reach cost and range parity with gasoline cars without subsidies. And by the way it has less moving parts, it's low-maintenance and is got a really good acceleration. So if you wanna go zero to 60 this is great. And so if you put all that together and you look for consumer attractiveness to this, I'm like this is amazing. Why won't you do that, right?

So right now and this is about we're talking of the United States. Most of the EV adoption is going on in China and India is planning to do the same because they are importers of oil, this is national security. And so if you look at the EV adoption I think we're gonna see when this early stage of this S-curve and this is going to go steep like this. The challenge and this comes back to the grid is can we, if we have, you know, we have California about 5% penetration of EVs, at 50% penetration of EVs it'll be like going to the airport and trying to look for a charging place for your phone and that's what we don't want to get into. It could introduce volatility on the demand side of the grid and you have volatility on the supply side as well because of renewables.

And the question that we all have to kind of address both with technology and policy, etc. how can we connect the two in ways that can even out the fluctuation and actually make it more stable and more affordable in the future. And that's a challenge that we all have to face.

Greg Dalton: There's another powered element to that, Hal Harvey, which is the oil companies and the electric utilities are now competing with each other. They're now swimming in each other's lanes. The electric utility industry as you say is largely state more local, the oil industry is very centralized. How is the power dynamics changing as these big industries now kind of are looking at each other's lunch?

Hal Harvey: Well one of the reasons that carbon tax went down in Washington because the oil company spent mightily to defeat it. What's beginning to happen as we turn the grid to zero carbon

electricity and then electrify everything, is the utilities come on side on environmental issues. The Southern Company which is one of the grand old monopolies covering five or six states in the deep south has said publicly, we'll put all the solar in you want as long as we get to own it, right. PG&E, Southern California Edison, San Diego Gas & Electric, California utilities have done heroic work on renewables and on EV charging. I think the way to go is to give the utilities the incentives to become the engines of this transition and let the oil companies just try to keep up. The only way to defeat oil is to crush demand for oil. And the best way to do that is to provide the same services in ways that are about cleaner and cheaper.

Greg Dalton: Kate Gordon, a lot of the politics of defeating oil are aimed at stopping pipelines, villainizing oil companies, attacking supply, that's where a lot of environmental and political campaigns aim to do. Is it effective?

Kate Gordon: I mean oil is complicated because it's a global commodity with very global price fluctuations. So we love to talk about oil as if it some local thing where, you know, one of the big things that happened in Washington was the all of this advertising saying gas taxes would go up and you got all these rural commuters who have to go an hour and a half to get to the hospital getting worried about gas taxes. That was the conversation we've seen it here in California. In fact that gas taxes don't go up materially because of local policy even local tax policy they go up materially because of disruptions in supply, including by the way Hurricane Harvey which disrupted supply, Katrina disrupted supplies. So it's challenging because it's a very global conversation but you can use it manipulate it locally. I think therefore local battles against oil don't do that much to disrupt the global supply chain. They are important because they build a base of environmental activists, they're important because it's a target that's easy to go against.

I think there have been some really effective campaigns the divestment campaign actually has been really interesting because it didn't actually lead to a whole bunch of divestment from oil but it led to a lot of really important conversation about reinvestment in other things and about portfolio diversification and about volatility in all kinds of stuff that's been really important. So I think it's hard to say the pipeline fight changed the whole dynamic because there's rerouting and there's global supply there's changes all the time but it is important for the movement so there's a sort of two different metrics. One quick thing on Hal's point though, just on oil, I mean we use oil for all kinds of stuff that's not electricity, right. So I'm just interested in your perspective on plastics and on some of these very difficult to electrify parts of the economy steel, concrete and that's more coal, but how do you look at that stuff?

Hal Harvey: Well, much of that is actually natural gas more than oil these days, because it's a simpler molecule and easier to manipulate. There are some sectors that are gonna be tough to decarbonize. Fertilizer, plastics, you mentioned, certain kinds of chemistry. And the way you get after them is you start now with really serious R&D instead of the kind of modest sums that we have in America so far. But if you dissect natural gas about a third of it goes into industry, a third into home heating and a third into electricity.

The electricity one is pretty straightforward. Home heating, we moved to zero net energy buildings and then industry it's gonna be tougher.

Announcer: You're listening to a Climate One conversation about zero-emission energy, zero emission transportation, zero-emission buildings and zero-emission waste. Coming up - is there a fifth zero?

Arun Majumdar: *If you look at food and agriculture itself and consider that if that sector were a country the CO2 emissions from that would be next to China, U.S. and then food and agriculture. That's where we are.*

Announcer: That's up next, when Climate One continues.

Announcer: We continue now with Climate One. Greg Dalton is talking about net-zero climate solutions with Hal Harvey of Energy Innovation, Kate Gordon of the Columbia Center on Global Energy Policy, and Arun Majumdar of the Precourt Institute for Energy at Stanford.

Let's get back to their conversation.

Greg Dalton: Let's ask you Arun about buildings. You've written a lot about buildings you even testified before Congress about net zero energy buildings. There are some rules on that Santa Monica wants to have net zero buildings. It is that really, you know, how hard is that, is it low hanging fruit to get to net zero energy commercial and residential buildings?

Arun Majumdar: Well Hal is really the expert in this. But let me just say I think zero net energy buildings I think there's a lot of R&D that has gone into it. The question really is zero net energy and if you could make it zero net cost, then it'll scale. And that's the difficult part. In the building side, in the energy efficiency side, you know, there are some market failures which is why we have had some very successful and Hal has written about this in his book on appliance standards, codes and standards. And if you look at the trajectory of, you know, for example, the classic refrigerator standards and there are many other standards appliance standards, they have had a huge impact. And by the way, standards are sort of the bottom line, right, there are energy star and there ought to be energy superstars as well to make it really, really efficient. But what we don't have are today we have building codes and codes are great I mean they have really brought down the energy consumption in buildings, etc.

But what the codes are for design and one of the things that I've mentioned in my testimony to the Senators. In addition to, so it's like, you know, you get a stamp, you get a code and you build it but it doesn't quite operate the way he have designed it, okay. So there are some LEED rated buildings and we're all very proud of a LEED rated buildings. But if you actually look at the data on how these LEED rating buildings actually operate there is no correlation with the rating whether it's gold or platinum there's no correlation. And so I think we really need to look at some kind of a standard based on actual measured performance. And once you do that and unless you measure, you'll never know where the problem really is. And the building may look beautiful from outside but it maybe crummy from the inside on the energy efficiency.

Greg Dalton: We know about that here in this wonderful new green building. There was an architect who designed it and they gave us the keys one day and said see you later and now we're operating it and may not be using it exactly the way -- Kate Gordon.

Kate Gordon: Both of you brought up these really important points about buildings and cars. And I just wanted to ask what you think about how quickly these fleets of buildings that are owned by individuals and cars that are owned by individuals. How quickly can we actually turn these things over? I mean people are, the Ford F-150 is still the most popular car in America. People are holding onto their cars longer now than they did before the recession. New houses have great standards but what about existing houses. We know retrofit policy does not have great uptake. So how do we deal with all this capital stock that's out there that needs to be transitioned?

Hal Harvey: On the vehicle side, there's a natural capital stock turnover and it's about 14 years for car about a million to a million and a half miles for heavy-duty truck.

Kate Gordon: People aren't always buying new cars after 14 years, they're buying off Craigslist they're buying used cars.

Hal Harvey: Yeah, but that's the life -- that's the average life of a car.

Kate Gordon: Right. Right.

Hal Harvey: That's take the two or three owners that it might have. It is slow and this is one of the things we have to deal with it. It puts a premium on starting early. So right now the most important building code in the world would be in India and China because they have less than build space.

Kate Gordon: More new stuff, right.

Hal Harvey: Exactly. Retrofitting homes and offices is more complex, no question. Some of the best programs have been run by utilities --

Kate Gordon: Because they're more centralized, right?

Hal Harvey: They're more centralized they have all the data they can raise capital very easily they can hire experts and get economies of scale and so forth. But I don't want to pretend that retrofitting houses is a simple thing. On the other hand most people do over the course of 20 years do a retrofit and at that moment they should put in better windows, better insulation in the ceiling and so forth.

Greg Dalton: If you're just joining us we're talking about zero energy economy at Climate One. I'm Greg Dalton. My guests are Kate Gordon, Fellow at the Columbia University Center on Global Energy Policy. Hal Harvey, an Energy Expert and author and Arun Majumdar, Co-Director of the Precourt Institute for Energy at Stanford University.

Hal Harvey, there is by your estimates gonna be another \$2 billion gasoline cars built.

Hal Harvey: Two billion in number.

Greg Dalton: Two billion total, so there's a billion now. So another billion built to get to two billion cars. So what can be done to, you know, a lot of people would like to hear that we say we have to get off gasoline we have to get away from gasoline cars, there would be another billion built. How much room is there to make the internal combustion engine more efficient is that for real or is that just kind of a Detroit party line?

Hal Harvey: There are huge opportunities to make cars more efficient. Both the engine itself right now the average engine in a car is a pathetically inefficient machine. Right now only about 10% of the energy you put in the car actually moves the car. So the engine starts off by losing more than 60% of it into forms of heat up the radiator and the exhaust pipe. But there are other frontiers we should pay attention to. Aerodynamics is getting better. Why is the underbelly of your car rough and the top smooth? An airplane, the whole thing is smooth for example. Light weighting, huge frontiers. The BMW i3 is carbon fiber from the knee up and aluminum from the knee down and it weighs 1,300 pounds less than the average American cars, a beautiful electric car.

Greg Dalton: The Ford F-150 is now aluminum.

Hal Harvey: The Ford F-150 bed is aluminum. General Motors is offering a carbon fiber bed in their pickup truck. Better tires, reduced auxiliary loads like lighting and even changing the paint. They have now these molecularly reflective paints that drop your engine -- the interior of a car temperature by 10°, and at the same color they look the same. And you can do the same with the glass. So there's no reason trucks shouldn't push into the 35 plus miles per gallon and cars well into the 50s without changing function or safety.

Greg Dalton: But during the Obama administration remember GM and Fiat Chrysler went bankrupt the auto companies were bailed out, they made a pledge to President Obama to increase CAFE fuel efficiency standards. They were the first industry after Donald Trump was elected saying, oh whoa new day. So tell us about that update of continuing the CAFÉ standards.

Hal Harvey: So that was a grotesque breach of faith which is pretty unforgivable. They cut a deal and the taxpayers bailed them out and they agreed to this comprehensive measure and then they did go in and ask for leniency. What they asked for was actually fairly mild, what they got was much more than they wanted. So right now you have the spectacle of both the unions and the auto companies protesting the Trump administrations rollback of automobile fuel efficiency standards. They set their targets, they're engineering toward them, let them go.

Greg Dalton: And how the U.S. standards compared to Korea, Hal Harvey, there's a chart in your book Korea, European Union, China, we're below all of that.

Hal Harvey: We were on the right track with the Obama standards by the way, those are still the law and the other thing to keep in mind is California has its own standards and 13 other states choose the Californian way. And the Trump administration is trying to revoke that right but they haven't managed that yet and I don't think they're going to be able to. So if we push cars into 54 miles per gallon, which was roughly the Obama standard it depends on the fleet mix, we're right up there with China, Korea, Japan and European Union. We're a little behind some, a little ahead of others but that's perfectly great territory.

Greg Dalton: Arun Majumdar, are robotic cars gonna push EVs adoption because it's easier to have a robotic car that's electric than internal combustion or is that just gonna not be a factor and make more cars out there because we don't care who's driving them.

Arun Majumdar: So when you say robotic cars I supposed you mean --

Greg Dalton: Autonomous.

Arun Majumdar: -- self-driving autonomous car. I think fully autonomous cars on the streets I don't think that's gonna happen in like very soon. When we actually look at fully autonomous then you don't need the driver there are tons of issues that we have. I mean, driving is actually a social activity. When you're trying to merge onto a freeway and you think about it there's a social connection that is going on and to emulate that on a computing platform is nontrivial. I think what will happen is that there are lots of places where the autonomy is actually going to assist the driver to reduce accidents and thereby actually would do save lives.

And I think that's where we'll foresee there's a lot of business incentive to make it fully autonomous because it will remove the Uber driver so that they actually, you know, it reduces the cost. But I think we'll see on trucking on some lanes we'll see that and that actually is really important because there are truck drivers driving in hours that they should not be driving and that'll reduce the number of accidents. So I think there are other factors that will drive this than just purely economy.

Kate Gordon: Well on those safety points go to light weighting too because one of the reasons we require cars to be so heavy right now is because of safety concerns. If those safety improvements are put in you could see a faster adoption of some of the light weighting technology which is pretty cool.

Greg Dalton: So technology assisted humans are still playing a role in there with lots of technology around them to keep us from doing the stupid stuff that we do.

Hal Harvey: I'm not dead yet.

Greg Dalton: Still hanging in in there. The carbon conversation tends to gravitate towards tailpipes smokestacks. Arun Majumdar, I want to talk about land-use, agriculture, deforestation, which often doesn't quite get the attention it deserves in the climate conversation. Your thoughts there on that being maybe what fifth zero?

Arun Majumdar: I think so. I mean, if you really look at the climatic equation energy and climate equation. I call it the simultaneous equation you got to solve. And that is we are at 1.2° or 1.3° above the global average temperature rise. If you want to keep the temperatures below 2° because the tail of that 2° is really bad. We have a budget of around 800 gigatons of CO₂ roughly 800 to a thousand, that's the debate, but it's in that range. We are emitting about 40 gigatons of CO₂ per year roughly globally. So you do the math. If the emissions are flat we have about 20 years and after that it has to be zero, okay. So that's the equation we have to solve. Now, given the economic growth that we are seeing in China, India and other parts of the world. We can't tell them not to grow because it's prosperity, etc. and they're trying and China is trying, India is trying to do that as well with renewables etc.

But the construction of steel and concrete are such that if they want to grow there will be emissions. And so the question is what else what's Plan B. And the Plan B has to be some level of negative emissions. I think if you look at all the predictions all the projections and calculations by IPCC and if you want to keep it below 2° you got to have negative emissions, so what's their negative emissions. If you look at the Keeling Curve that is the CO₂ going up and down. Why does it go up and down? It's because of photosynthesis. That brings us back to agriculture, forestry, reforestation, afforestation, etc. And we got to figure this out that how do we take that one lever that we have and use that to induce negative emissions.

Greg Dalton: And just to jump in there. In the spring there's lots of foliage that then sucks carbon out in the fall it falls off the carbon goes back in, that's a fluctuation.

Arun Majumdar: Because in northern hemisphere we have more plants than -- more lands and plants than in the southern hemisphere that's why I see this oscillation. Now, on the other end so that's what we desire that's what we want to see. We want the plants to suck out the CO₂ from the atmosphere and put it deep in the ground because most of it goes back and we don't how to do that yet. But on the other hand, if you look at food and agriculture itself and consider that if that sector were a country the CO₂ emissions from that would be next to China, U.S. and then food and agriculture. That's what we are. And so I think we are on the wrong end right now we got to turn that around and see how we could use that to induce negative emissions keep it down on the ground. And that's where the R&D and the policy all of that should be going as well.

Greg Dalton: Hal Harvey your thoughts that there's been, you know, too much focus on metal and pipes and not enough on nature using soil agriculture to try to put carbon back in the ground that we've taken out of the ground, burned it and put in the air.

Hal Harvey: Well certainly the first thing we should do is stop deforestation altogether and look at realms where we can do afforestation and let nature do what nature does best. Nature fixes carbon in the soil and of course in the biomass itself. I'm a little nervous about large-scale plantations to be used for either biofuels or to be burned and then have the carbon sequestered even though it makes you carbon negative but because it would require very large alterations on the landscape with who knows what ecological issues. And it puts food and fuel in competition with each other. And when rich people's fuel is in competition with poor people's food we know what's gonna happen it's not gonna be pretty.

So I guess the way I would think of, I think the way to think about this is because we have a very limited carbon budget it's staggeringly small compared to business as usual. We need to look at the options to take the biggest hunks out of it the fastest. So it's all about scale and speed. There will be stuff we have to do 30 years from now to clean it up to finish the job. But you can't, you don't have the luxury of doing the last 5% unless you've done the first 95%. So we need to go after speed and scale. And that requires tackling the four big energy sectors.

Greg Dalton: Kate Gordon.

Kate Gordon: Yeah I think that's, I absolutely think that's right to go after those four big sectors. But we know from the latest intergovernmental panel on climate change report that just came out about how to get to 1.5° which is what the island nations believe we need to do so they're not underwater. We need to start thinking about carbon removal now. We can't wait for the second half of the century to start doing the research and development and getting this to scale and figuring out the technology and stopping deforestation because these things have got to be part of the current solution.

And I would just go beyond land side and say I am really interested in some of the more engineered solutions. They are still pipes and industry, but it's interesting things like how do you do direct air capture to get carbon directly out of the atmosphere and then sequester it. What are other there's something called enhanced weatherization or mineralization where you take a natural process where certain types of rock bind to carbon already and you basically crush the rock so that there's more surface area so more carbon binds to it and you spread it over a larger area. People are looking into some of this stuff now it's expensive but we need to figure out whether you can do it whether it can be safe whether it can be done at scale whether the technology can get cheaper. There's also a very cool stuff that I think is cool because it's at the intersection of the built environment piece and the carbon piece which is how do you take carbon dioxide or methane and turn it into products to replace plastics to replace petrochemicals to replace furniture to replace building material sometimes. That's very cool that whole set of things and I kind of I worry that we will think all of that is a later problem and we know from all of the modeling that we actually need to be doing this at the same time.

Greg Dalton: And there's part of the shift of carbon not being the enemy carbon being an input rather than something that thing, Arun Majumdar, you know, put it into cement, putting carbon as a resource rather than enemy that we have to drive a dagger into the heart of it.

Arun Majumdar: I think what is really missing is the sense of urgency. Because if you look at 1.5° it's about 13 years. If you look at 2° which is what we agreed upon in Paris it's 20 years. Either way you take it, it's 13 or 20 years, I mean that's the range. So some of us may be alive out there but our children and grandchildren will certainly will have to face the brunt of this. And that is -- and after that by the way, it's zero. And we have to figure out in the next -- this is all hands on deck, it is not, you know, we get into the tyranny of or, it is the time for and. And I think that's what we need to put all hands on deck in trying to address this.

Announcer: You're listening to a conversation about zero-emission solutions for a two-degree planet. This is Climate One. Coming up, will big industries bring out the big guns?

Arun Majumdar: *How many industries are there today at the gigaton scale? There are only six. It's oil, gas, coal, steel, concrete, agriculture, okay. So these we have to convince them to be part of the solution as opposed to being part of the problem.*

Announcer: That's up next, when Climate One continues.

Announcer: You're listening to Climate One. Greg Dalton is talking about four-zero climate solutions. His guests are Arun Majumdar of Stanford, Hal Harvey of Energy Innovation, and Kate Gordon of Columbia University.

Here's Greg.

Greg Dalton: There's a focus often, Kate Gordon, on voluntary virtuous action what can an individual do because people feel frustrated that policy is elusive and it's slow. So is there a role for voluntary virtuous is that necessary and insufficient?

Kate Gordon: I mean we are, just to echo Arun, we're in a period of and so everything matters, right. It matters at the scale of me as an individual, you as an individual; it matters if it's about you replacing your boiler in your company. It matters if it's about you controlling an entire supply chain. All of these things are really, really important. I struggle with this all the time because three of the biggest things one can do as an individual to reduce carbon impact are stop flying, don't eat meat, and don't have children. And those are all hard; those are hard things to ask people to do. I will say that I am, the more and more I had these conversations about the food piece of this, the more I'm moving toward the not eating meat.

And it's one thing that is doable but I know this is frustrating to people. I also think that you can vote, obviously that's a huge thing you can do to influence this conversation. Also, anyone who is an investor I spend a lot of time talking to investors and investors need to start thinking about the stuff. Looking at companies that aren't paying attention to their climate risk that aren't doing some of the actions they can do at a much larger scale to solve these problems, we all should be voting with our feet and voting with our wallets and doing more because it isn't useless to do more.

Hal Harvey: Can I be the skunk at the garden party.

Greg Dalton: Please skunk it up.

Hal Harvey: I think the essence of strategy is making choices and then focusing on them very hard. I think the opposite of strategy is trying to do everything. Our biggest shortage in the world is political bandwidth and political courage to do the right thing. And if we spend that political bandwidth stopping this pipeline or divesting New York's pension fund from coal stocks or trying to convince our fellow citizens to be vegetarians we're not using that to decarbonize the grid move to electric vehicles and so forth. And let me just take one more sec with this. So there's this crowds of people at 350.org who have been all activated and none of them, not none of them, but very few of them are actually working on the things where the zeros are and so we lose.

Kate Gordon: It's very hard for individuals to work on policy. It's very far away from us people. It is not within people's day-to-day lives.

Hal Harvey: Isn't that what an election is?

Kate Gordon: In a non-direct, in an indirect way. I think there is still really, I really think there's value in mobilizing the base, energizing the base. I think there's value in keeping people involved because they then are advocates.

Hal Harvey: We got to point them in the right direction.

Kate Gordon: I just think I think that people have an easier time fighting a thing they can see or that's affecting them directly or arguing about a tangible object like a pipeline. It is just easier to do that. What I like are the times when those actions and I'll bring up divestment again because it's striking to me. I was one of those people on the divestment movement who said if you actually look at the numbers this isn't gonna work and it's not gonna make that big of a difference because all of the state-owned oil and gas in the world and all of the decisions that are not made by investors. It turned out that the divestment movement actually made a really big difference in a different way in that it led to a bunch of universities having a very serious conversation with their investment teams which they would not have had otherwise. And a bunch of endowments doing the same thing and actual company behavior shifts because of shareholder actions that was important and vague it wasn't what they meant to do, but it was an important outcome.

Hal Harvey: Can you name any oil wells or coal mines that were shut down because of lack of capital? Not lack of returns but lack of capital.

Kate Gordon: No, no. But that's my point is that it didn't have the impact that it was designed to have but it had a broader impact in a bunch of different sectors. I really do think it did and it led to some divestment from coal from some endowments and from some universities.

Hal Harvey: But it didn't shut the coal mines down.

Kate Gordon: My point is just that it had an impact that was beyond mobilizing the base.

Greg Dalton: Arun Majumdar.

Arun Majumdar: Yeah, let me just echo what Hal just said. We have a gigaton scale problem, okay. It's not a megaton it's a gigaton. We emit 40 gigaton --

Greg Dalton: Aren't you get ahead around what that means.

Arun Majumdar: It's a lot. It's a huge amount.

[Laughter]

It's big. And we need gigaton scale solutions. If you focus on things that even at its best can do a few megatons a few hundred megatons it ain't gonna cut it. And I think we should look for solutions that can scale, scale is everything, both in volume and mass of the gigaton and also be cost-effective. Because if the economics doesn't work it just ain't gonna cut it. So I think that's the challenge that we have. One of the solution and in fact, we wrote a report, Ernest Moniz, former Secretary of Energy advisory board and he asked the question, what do we need to do? And this was, he gave us only six months to write this report, we did it.

And what we basically said is that if you're looking for gigaton scale solutions and he asked, how many industries are there today at the gigaton scale? There are only six. It's oil, gas, coal, steel, concrete, agriculture, okay. So these we have to convince them to be part of the solution as opposed to being part of the problem. And I think that's why we need to engage with them and make them realize that this is a historic opportunity for them to be the stewards of this earth, not just the stewards of the shareholders. In fact there are shareholder pressure to turn that way right now.

Greg Dalton: We're talking about low carbon economy at Climate One with Kate Gordon, Fellow at the Columbia University Center on Global Energy Policy and Hal Harvey, energy expert and author. And Arun Majumdar, Co-Director of the Precourt Institute for Energy at Stanford. I'm Greg Dalton.

Let's go to audience questions. Welcome to Climate One.

Male Participant: Hi, my name is Matt Renner. I think that the last question was about the political will, right. And we actually have an analogy which is World War II. We mobilized in an incredible speed to actually build momentum to fight fascism. America became the production engine that won the war. What can you imagine happening what is the political frame or what is the social frame that actually gets us to gigaton scale, actually leapfrogs from things that could scale to things that are scaling. And gets us there in 12 years not 20 not 30 before it's too late and before more towns are burning to the ground. Thank you.

Greg Dalton: Kate Gordon, kind of the framing person.

Kate Gordon: It's a really hard question. I think the thing that I struggle with a lot working on this issue as I've done for 20 years on climate change is that while the problem is inherently global the impacts are extraordinarily local. The impact here in California right now is wildfires it will be mudslides next year, probably whereas the impact in Houston is something else, whereas the impact in the northwest is ocean acidification whereas the impact. So it's very, very local the timescales are different it's not all hitting everyone at the same time. And there's no global governance mechanism other than the UN, which is flawed for this that to solve it.

Arun Majumdar: I think G20.

Kate Gordon: So G20, I would like to see the whole thing shift over to be an economic issue and not in sort of the bucket it's still mostly in which is sort of environmental negotiations. If we could get shift this over to -- the focus of G20 at the World Economic Forum already in its 2018 global risk report highlighted environmental risks climate impacts and transition risk and litigation risks from climate change are some of the biggest global risks that we're facing. I think that's a start, it sort of moving it.

So what it's gonna take, it's gonna take shifting this to become a global economic crisis that builds on all of the local impacts and builds them up into something shared. I think that there's some hope, you know, we sort of created a situation in which China has turned to Europe as a new natural ally in the climate fight, that's actually not necessarily a bad thing in terms of creating momentum creating markets and moving some mindshare toward this. Do I think it's gonna happen in 12 years? It's really, really tough because not only do you have local impacts but you have local political actors who are reelected all the time. As we know, we just set ourselves back in this country, we set ourselves back during the Reagan era in this country, we continually -- Australia was a leader and then it wasn't. UK was a leader and then it wasn't, it's extremely challenging but I think if we can make this into something to me it's a macroeconomic issue like globalization and like automation. This is coming, we need to deal with it, it's something we all need to get behind whether we're in the private-sector the public sector and it's a large fight. I think that's what we need to do.

Greg Dalton: Hal Harvey.

Hal Harvey: Just two words of hope. First one is millennials. I think there's an opportunity with the next generation they're not voting in -- if they voted in the numbers they should we have this one licked so that's an issue. The other scaling machine that beats all scaling machines I suppose is China, right. And the Chinese government take science seriously and they are seriously battling climate change, but they are also building coal-fired power plants. So it's a race of good and evil and evil has a big head start and good is accelerating faster but we don't know how that one is gonna come out. But it is amazing the transformations already.

Greg Dalton: Let's go to our next question. Welcome.

Female Participant: Thank you. My name is Xing Yi from Alameda. I have had this growing concern that we may actually have less time than we think we do because the carbon accounting has been wrong certainly with municipalities. The carbon markets have gotten the carbon accounting wrong and I'm wondering if there's a realization in other areas as well about this.

Kate Gordon: Just really briefly on this. I will say that politics plays a role too. One of the biggest concerns that I have right now is that the new Brazil president who's just combined the economic and agriculture departments will deforest a huge amount of the Amazon. That would change the carbon budget if that happened and that would be a political decision that would have huge implications. So I think we can't control it necessarily that's one important point just on the political side. I won't get into the accounting side. One of you guys might want to.

Arun Majumdar: So I'll tell you where the risk is I mean I completely agree with the person who asked the question. So if the permafrost starts warming, it is warming, there are organisms out there called methanogens they generate that eat the carbon in that soil and they generate methane. When that methane goes up in the atmosphere that has a global warming potential anywhere from 30 to 60 times that of CO₂. And that is a positive feedback that we have not accounted for in our climate models. So just to give you the -- it is scary, sorry to say this. Because if that happens so that's a tipping point that we reach, it is irreversible. I think frankly in many aspects of this and someone asked me about 2° I think 1.5° is already baked in because most of the heat is being absorbed in the oceans, okay. And we are creating a new ocean the Arctic right now and the Antarctic is melting. So this is all real and I think that tipping point, I don't know when, no one knows when we're gonna reach that --

Kate Gordon: Which is why it's not on the models usually.

Arun Majumdar: It's not in the models and that's a positive feedback tipping point.

The Stone Age did not come to an end because of lack of stones. I think the fossil fuel age will not come to end because the lack of fossil fuels. We have to come up with new solutions exactly what you said earlier. And that's what we should be looking for.

Announcer: We've been talking about zero-emission solutions here at Climate One. Greg Dalton's guests were Arun Majumdar, Co-Director at the Precourt Institute for Energy, Stanford, Kate Gordon of the Columbia Center on Global Energy Policy, and Hal Harvey, CEO, Energy Innovation. His new book is *Designing Climate Solutions: A Policy Guide for Low-Carbon Energy*.

To hear all our Climate One conversations, subscribe to our podcast at our website: climateone.org, where you'll also find photos, video clips and more. And join us next time for another conversation

about America's energy, economy, and environment.

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