Dean Kelley: When it comes to climate change, it's important for all of us to think in new ways. And here at Duke, researchers are exploring lots of exciting new areas. Can we, for example, use artificial worlds to improve access to energy data, or are there ways to track climate change with satellites and artificial intelligence? I'm Judith Kelley, Dean of the Sanford School of Public Policy at Duke University. And this is Policy 360, and this is the first in the series of conversations that connects research and climate change. My guests today are Marc Jeuland and Kyle Bradbury. They're working on the tech projects I just mentioned. Kyle Bradbury is the managing director of the Energy Data Analytics Lab at the Duke University Entity Initiative and he brings experience in machine learning and statistical modeling to energy problems. Welcome to Policy 360, Kyle.

Kyle Bradbury: Thank you so much, Dean Kelley really appreciate the intro and excited to be here.

Dean Kelley: Excited to have you. And Marc Jeuland is a faculty member here at the Sanford School of Public Policy at Duke University and recently he has been doing a lot of work related to climate change and water. So welcome to you, Marc.

Marc Jeuland: Thanks Dean Kelly. Very happy to be here. Thanks for the invitation.

Dean Kelley: It's so great to have you. So Kyle, I thought we would start with a project that's currently just in the planning stages for you and it's related to tracking climate change with satellites and artificial intelligence. So first tell me, where did you get the idea for a project like that?

Kyle Bradbury: This has actually been a project that has evolved over a number of years of research and collaboration with folks across Duke and beyond, where our group has been working on exploring how satellites and remote sensing data can be used to inform energy systems and planning of energy systems and understanding the state of development of infrastructure related to energy and climate systems. So we've had projects going back a few years, looking at identifying solar photovoltaic arrays, the solar cells we typically see on rooftops, trying to do that across the globe. We've had projects looking at how to identify transmission and distribution lines to see how the development of those key pieces of infrastructure were progressing across the globe, all using satellites and remotely sensed data.

Dean Kelley: And is that kind of tracking is not systematically being done by other intelligence agencies or environmental agencies around the globe?

Kyle Bradbury: Yeah. So for example, in the US, there's no central database of solar PV, the Energy Information Administration, which is a great source of data, has state level estimates. Your particular county or city may have local or regional estimates, but there's no aggregator of that information. So if you want to say, well, how many solar arrays are in my neighborhood? That's actually a harder question than you think.

Dean Kelley: And that kind of information is relevant to climate change in particular how?

Kyle Bradbury: They're actually a number of ways that we could use this sort of information. So for example, when we think about land cover and land use changes that might be present, the addition of agricultural land or deforestation, impacts of any sort of natural disasters on land use. These are things that sometimes can be quite challenging to actually monitor in real time. But with satellites, you've got snapshots of the entire surface of the earth either every day or every week, depending on the particular satellite that you're looking at. So there's a lot that we can do there with understanding evolving vulnerabilities to climate change, assessing damaged areas of land following natural disasters, and enabling real time tracking of infrastructure like energy systems, transportation systems, the development and expansion of electricity access in other locations. So there's actually a real lot that we can learn from that.

Dean Kelley: I suppose we're all very used to running to the supermarket when we hear a storm is coming and we need to get extra water and we need to get batteries for flashlights and all these types of things. And I suppose this is one way that infrastructure is impacted by weather. Are there other examples, Marc? I know you're an expert on water. What are the infrastructure weaknesses and vulnerabilities that your data needs to try to map for us to understand the climate change impacts?

Marc Jeuland: Yeah, sure. I mean to give a very salient example right now, some of my work in the past has looked at hydropower dams in the Blue Nile Basin and Ethiopia. And these are projects that depend on the flow of water. You have to push the water through hydroelectric turbines to generate electricity, and downstream, farmers care a lot about what the water releases will be from that dam. So in that particular context, it's quite shocking, but there is no publicly available data on flows in much of the Nile that planners can use or that micro-level actors like farmers, city residents can use to understand when there's going to be a shortfall of water. But with satellite information, in theory, you can start to see, is the water flow actually low or is it something related to the operations of that infrastructure?

And that's really important for having trust in the system because if you're a downstream farmer and you don't get water, there are two possibilities. One is that it's very dry and there is no water. And the other possibility is that the water's not being released properly to meet your needs. And those two things are quite different, but they can get conflated in people's minds, leading to all kinds of negative consequences.

Dean Kelley: Absolutely. Kyle, what are some of the other systems that we should be thinking about here that are vulnerable to climate change? I imagine things like our energy grid, our transportation systems, what is it that the normal consumer may not think about when they think about infrastructure systems that are vulnerable and ways that they are vulnerable, other than direct hits?

Kyle Bradbury: There are two things that are important to think about here. There's the direct impacts. For example, if a part of the electricity grid went down, or if part of the transportation network went down, then there are the indirect impacts that are due to the correlations between some of these systems. So if the electricity goes down and there are pumps that are needed to move other types of fuel for transportation systems, then that might affect transportation systems and vice versa, right? So there's those interactions where we think, oh, well the grid went down in this part of North Carolina. Well, that shouldn't mean that I shouldn't be able to still get my packages that are being delivered, but very likely those systems could be impacted as well.

Dean Kelley: So the extent to which we have vulnerabilities in the system is also itself a function of the extent to which we have been able to adapt the systems, to build them in a way that they are able to handle certain types of stressors. And I imagine, Marc, for example, that when it comes to water systems, that this may actually vary. In poorer countries, these systems are less robust. Or do we know anything about that or does the data that's being collected pick any of that up?

Marc Jeuland: Yeah, it's a great question. So whether the data pick this up is still very much a work in progress. I don't think so generally. And that's because where we typically have the worst data is also in under-resourced kinds of places. So it's harder to answer that question, but we also know that there are particular vulnerabilities in those places. And the other issue, I think that's important here, is that climate change is a very dynamic phenomenon. So essentially what we see now is not what will be happening very soon. And so I think one of the big problems is that the most vulnerable systems are actually perhaps the most complacent ones, the ones where there hasn't been prior exposure to large shocks. And that's because people are not ready, they haven't adapted and infrastructure hasn't been adapted. So those places where there haven't been a lot of stressors and shocks historically, but there will be, are also among the most vulnerable. And that's a bit counterintuitive because that's also where we know the least about what will happen.

Dean Kelley: That's fascinating. And often the case that the losers are the places that are already disadvantaged. Kyle, I was wondering, you mentioned that oftentimes the vehicle for impact is a storm, but are there other weather related phenomena such as heat, for example, or extreme freezing that can also stress different infrastructure systems?

Kyle Bradbury: Oh, absolutely. I mean, if you've driven by a transmission line on a particularly hot sunny day, you may have seen the lines themselves sagging a little bit because these materials expand in the heat, causing them to sag a little bit more. That in of itself is not a problem, but what can then happen is if it sags too much and the carder for that transmission line, if it hasn't been recently pruned of its vegetation, it can make contact with local vegetation causing potential outages. Additionally, one impact that's maybe less obvious is the impact on the cooling systems of power plants. A lot of steam power plants rely on cooling water often taken from nearby bodies of water, ponds, lakes, rivers, et cetera. And if the temperature rises in those waterways, it can affect the efficiency of operation of the plant. And of course, if the cooling water begins to dry up, or there is less of that available, that also can massively impact plant performance, which Marc, I'm not sure if you've been seeing some of that in your work, on the hydropower side as well.

Marc Jeuland: I was going to mention cooling water in the context of generation because traditionally planners of water resource systems, they don't really think about cooling water as an important use of water because the water is generally returned to the environment. But of course, this is an important connectivity between heat and water systems. If you start getting droughts and you don't have sufficient water to provide that cooling and power plants go down, then it could create a cascade of various sorts. And it also starts to become more of an urgent consumption issue because you now have more evaporation of water. So that water is being lost as you're using it in this non-consumptive use.

Dean Kelley: Marc, I want to ask you about how you think this data that's being collected might be used to inform specific types of policies. But before I ask you about that, I want to ask you Kyle, about nuclear power plants. In what ways are nuclear power plants vulnerable to phenomena related to climate change?

Kyle Bradbury: There are a couple things I think that are worth noting about nuclear power plants. One is that the designs of nuclear power plants have changed considerably from days of those designs that went into Chernobyl, right? So modern nuclear power plant designs are much more robust, much safer and are far less likely to be negatively impacted by any shocks to the system. That being said, there are still many designs out there of older nuclear power plants that have a degree of vulnerabilities present. When we're thinking about those systems, I mean, we've seen in Fukushima the potential impacts of a tsunami situation where the actual incident itself was due to the ability to then control how that plant was operating in the face of that flood. But it will be the case that a lot of nuclear power plants are not too far from bodies of water, and of course, flooding will be a potential source of concern for these.

Storms also could pose some concerns, but far less so for plants of more modern designs, unless it were to be hit by a direct hit by a tornado or a hurricane, it's pretty likely to be able to weather a storm like that. So I think there certainly are concerns. While some of the evidence is on the impact of climate change on storms is showing increased variability, it's worth continuing to keep an eye on the nuclear fleets globally to see if those storms will end up, increase in potential storms could interact with the presence of power plants and cause them to malfunction. But again, I think as we're looking more so towards the future, modern designs of these systems could really help to provide even additional fail safes in those situations.

Dean Kelley: So what you're saying, Kyle, is interesting because Marc, what Kyle is suggesting is that we've actually seen adaptations sort of since Chernobyl and over time as we've gained technical knowledge and that we can adapt some of our infrastructures to make them more resilient against these climate change threats that we are seeing. And that's certainly one approach. And so I'm wondering with this data that we have there from a policy perspective, what is it you think is the highest potential to use that for? Because one way is to think about using the data to inform how we are adapting infrastructure. But I suppose that as we gather more data, particularly in areas of the world where we have a less comprehensive existing mapping of the infrastructure, we might also change some of our estimates of the costs of, and the risks that come with climate change, which might change our calculations of our willingness to spend on mitigating the problem. So I'm just curious about your sense about those.

Marc Jeuland: Just to step back a little bit in terms of the potential uses for this data. I think I would categorize it into three different buckets perhaps. And the first of those is reactive. So this is essentially disaster response or event response, where you need to know exactly where things happened and how bad they were in those different locations. This is particularly valuable for remote locations that are hard to reach because there aren't a lot of communication networks, there may not be a lot of population even. You don't actually get good information about what the exposure was. And another example of a particularly useful application in terms of reactive policies and disaster responses in the insurance payout space, generally you have to rely on people to report damages and there are all kinds of reasons why those reported damages might not be accurate. Some of it could even be due to fraud. So having some kind of objective measure of where something happened and how bad it was, can help guide better insurance payouts to really reach those people who are affected negatively. So that first bucket is kind of reactive disaster response.

Dean Kelley: Right. How do we help people and how do we compensate people?

Marc Jeuland: Right, and how can we do it quickly? Because these are very dynamic events. Sometimes they're hyperlocal, something like a flood could just affect a small part of a land area where you knew something bad happened. There was a big rainfall event, but you don't know who was really harmed.

The second bucket is what I would categorize as making predictive explanations for planning. So where you want to essentially anticipate risks as they're evolving, before they emerge and harm a lot of people. And this is sort of in the adaptation space, how can you best plan systems for what's going to be coming and using information as productively as possible?

Dean Kelley: More proactively than reactively, yes.

Marc Jeuland: Correct. And this is difficult because predictions are made under uncertainty. You don't know for sure what's going to happen, but you can start to think about where those risks are increasing and you can sort plan infrastructure improvements or other kinds of softer policies that would support people. Think about moving people, if necessary, out of very disaster prone areas. And these kinds of decisions will reduce the costs of those negative climate events by a lot, if they're effective.

And so that's the third bucket essentially is the evaluative function, which is if we're making policy and planning decisions, we want to know what's effective and what works. And you can't know that if you don't have data and information and traditionally the way we've done this is often through surveys, which are very labor intensive. It's hard to get surveys into places when something happens. So there are all sorts of measurement problems that one confronts, not to mention that whatever you're measuring in surveys is somewhat subjective. It's reported by people who may have strategic reasons to answer in particular ways.

So what better satellite imagery can do is give you more objective verification of what's been found in surveys, and it can do it essentially in real time, which is one of the things that's most exciting about Kyle's project is that you can do this in a dynamic sense, sort of tracking things over time. Whereas a survey, you only get snapshots at moments in time, every once in a while. And so I think there's a lot of potential for combining these methods, but also the satellite methods on their own can tell you a lot about what's been effective and what hasn't been effective. If series of investments have been made and you still see the disasters affecting the same number of people, then that tells you something about the effectiveness of those policies.

Dean Kelley: Sure. Yeah.

Marc Jeuland: And you can make better decisions next time.

Dean Kelley: So Kyle, Marc has both reactive, proactive and evaluative uses for your data, which is great. You are collecting some other data as well in a different project that is about how to create artificial worlds with artificial intelligence and use those worlds to improve access to energy data. I am not quite sure I'm following. Can you explain, is this a game? Can I play it?

Kyle Bradbury: As I had mentioned to a few of the students who were engaged in this project, think the game Sim City, but for better understanding our energy system globally. There's value in particular from satellite data when we're able to really scale this up globally. But in reality, the techniques that underlie all of these analyses are different types of machine learning techniques and applying them globally is pretty hard. We typically need some sort of what we call training data. Basically, if you wanted to teach an algorithm what a solar panel looks like, you have to show it a lot of examples of solar panels.

So when we typically do that, we say, okay, well, we grab some data from a couple of cities. We label them by drawing some boxes around the solar panels and say, okay, algorithm, here, learn from this right as to what a solar panel looks like. But in reality, we've only fed in data from a couple of cities. When you think about the ambitions for the applications of these type of technologies, we want them to be global. We want them to be able to be applied broadly, but a typical rooftop in Boston, Massachusetts may look very different from a typical rooftop from somewhere in Southeast Asia or somewhere in Africa.

Dean Kelley: So I can really relate to this because this is about how I also want Siri to be able to understand a Danish accent.

Kyle Bradbury: Interestingly enough, there's some similar technology underlying both of those. Hopefully we'll have more success with the satellite imagery, but yes. So how we're working to overcome that and say, well, okay, well you have two options. One is say, well, let's give it examples from every place on Earth. Well, that's probably a little bit infeasible. So the other option is to say, well, what if we were to create an artificial location? Maybe we have an artificial Kigali, Rwanda, and we have an artificial Boston, Massachusetts, and an artificial Shanghai, China, right? And we can take artificial versions of these, you can imagine a 3d model of a city, but we're taking overhead images of it and use these synthetic versions of the location as a way to teach these automated techniques to learn to identify the types of infrastructure or natural resources that we're interested in.

So that's what that project is focused on. It's trying to use new approaches to create these synthetic, these artificial versions of different places in order to allow us to really analyze data globally and not have it be biased towards a handful of cities where we happen to have some data from.

Dean Kelley: So why is the work of creating these artificial cities not comparable to actually just surveying everything around the globe to make sure you are covering everything?

Kyle Bradbury: Well, we can do this much more quickly and much less expensively than if we were to try to survey everything across the globe. We can create some artificial data for a region in a matter of minutes to seconds once we have a few key pieces in place, and we can produce as much data as we need to help these algorithms to adapt to these different geographies. Now that's not to say that these things work perfectly by no means, but this is a line of research we've been working on to really push the bounds of what's possible with translating from North Carolina to Rwanda, perhaps.

Dean Kelley: Marc, you emphasized the reactive, the proactive, and the evaluative uses of the real data, but those uses are not particularly applicable, it seems, to artificial world data. So how is artificial world data then helpful from a policy perspective? Do you have any thoughts on that, Marc?

Marc Jeuland: So I would ask Kyle to correct my example, if I misspeak here about how it could be used, but one idea is that suppose that you're trying to understand the dissemination of off-grid solar in Africa. And we know that off-grid solar is just taking off in many places. So there's not a lot of it in vast landscapes in Africa, but maybe there is some in specific hotspots and locations. You don't know where those are before you start. So with Kyle's approach, I could imagine that maybe we take some imagery from a variety of different settings in Africa, some urban, some rural locations, different countries, maybe there's somewhat different landscape. Some are more forested, others not. And you've got a bunch of buildings in those images, but not a lot of solar panels.

If you could put these solar panels on those images, you could train your algorithm to detect them where they actually would be. And then you could apply your algorithm to a real Africa and see actually where the solar panels really are without having to hunt for them to do your training. And also without having this concern that the training is only applicable and specific hotspots like rural Kenya, where there's lots of solar.

Dean Kelley: I see, that sounds really convenient. Kyle is a correction needed?

Kyle Bradbury: No correction is needed. I will say that that is exactly one of the ways that this can be applied. And it could even be that you take an image from Durham, North Carolina, and you find clever ways of making it look like somewhere in Africa, through the use of some of the advanced techniques that have been emerging in the computer vision space. So yes, that's spot on, Marc, and there's even more.

Marc Jeuland: And so then this is valuable because if you now know where those solar panels are, where the effort has to be scaled up. We also know pretty well at a country level, how many people are connected to electricity, but we have no idea where those people are. The people who do, sometimes the government knows a little bit because they know where the grid goes and people on the ground know that as well. And we can map out the grid, but even the grid itself doesn't really tell you who's connected because there are many people who live under the grid, so they're right next to it, but they don't have a connection to it. And you would expect that those are the types of people that might also have solar panels if there is a solar market there. And if there isn't, then a promoter could go and start marketing solar panels there, and that's going to be valuable information, therefore, both for the government, but also for these private companies that are trying to fill the gap.

Dean Kelley: So we've been talking about different ways that technology can help us in the fight against climate change. And I'm wondering, there's sort of a line of thought out there that is climate change is definitely happening. There's definitely a bad thing, it's happening too fast, but technology to the rescue somehow. So where are you on that spectrum of techno-optimist versus climate pessimist?

Marc Jeuland: So I'm a bit in the middle. I definitely think that we have a lot of possibility to address this problem and many relevant technologies exist, although we need more, but where I'm more of a pessimist is whether we have the will to actually implement the policies that are needed to support that technological deployment. And that's where if I start to think about the political process and how climate impacts are going to play out, I start becoming more pessimist because I think that a lot of the misalignment that we have in our politics is because of lack of good information that people have. And then also people not really understanding the risks properly to support the types of political leaders that we need to enact changes. I also think that we have a major problem with special interests kind of capturing the policy process.

Dean Kelley: Yeah, and Marc, I mean, I think you bring up a really interesting point around the politics. And I'm curious, Kyle, whether you think that the kind of data that's being collected could potentially help change political calculus in certain locations with, as Marc mentions, better information. If you have better information, a policymaker might actually realize that their district is at risk in ways they had not appreciated prior.

Kyle Bradbury: I'm a strong advocate of transparency in data and access to data. I think we can all benefit from more information about climate, about climate change's impacts on infrastructure, about our systems and how they're working. And there are number of groups out there that are starting to take this quite seriously. The Climate Trace Consortium is one of them that certainly comes to mind that is trying to create high-resolution real-time estimates of carbon dioxide emissions globally. And trying to break that down by each of the sources that lead to that. I think that's the type of information that if we're able to say, okay, well, let's look in my neighborhood. What are the big sources of emissions in my neighborhood, my city, my state? Being able to know that for policy makers to be able to see and to have there be trust in that information, that will lead to evidence-driven decision making, which I think is where we want to be to really do something meaningful in this space that will all be able to benefit from.

Dean Kelley: Well, while we're on such a constructive path of thinking, I want to ask both of you, what is most exciting to you in terms of some of your own work that you could share?

Kyle Bradbury: I'd kind of group it into two buckets. Marc, I know we've been using a lot of buckets today, so I'm going to bring out two more. The first is around looking at the energy and climate space and what's kind of exciting there. And then the other is specifically within the connection to satellite imagery, remotely sensed data, and how that interacts with all of that. So when we're looking at energy systems and climate, we see a few major trends right now. One is the incredible increase in economic viability of wind and solar. The rapid increase in the maturity of technologies like energy storage, which allow for more asynchronous transactions. And there's a lot of flexibility that adds to the grid.

And then things like increased safety in modern reactor designs and things that are maybe a little less obvious, but I think are super exciting things, like increasing efficiency of lighting and our everyday appliances, which is bringing down demand even in a time when we're seeing increased use of a lot of different appliances.

So all of those are coming together, this distributed generation, asynchronous generation and greater efficiency to really change the way that we think about our energy systems infrastructure and in a way that provides a lot more levers for system operators and policy makers and corporate actors to explore, just to see how we can evolve our conception of the energy system, which in the 1990s and 2000s was almost thought to be old news.

Dean Kelley: Right? Yeah.

Kyle Bradbury: That's kind of on the broader technology front in the energy space. What I'm hoping that all of the technologies in bucket two on satellite imagery can help to inform the development of. So bucket two, I'm thinking about how we can continue to add real-time information, global information about all of these systems as transparently as possible. And there have been a lot of advances recently in computer vision techniques to explore and extract insights from satellite imagery, aircraft data, drone data that can help us to better understand the world and the systems around us. And I think that the core algorithms behind all of that work, which are rapidly improving, as well as the hardware advances to allow us to do all of that quicker and more energy efficiently will really help to provide a positive feedback cycle between the technologies that they inform and the policies that they can inform. So I'm very hopeful about what that will enable, not just the research community, but the broader community of decision makers operating in this space to develop over the next few years.

Dean Kelley: So not just one but two buckets of things you're excited about, which is great. Marc, how many buckets do you have?

Marc Jeuland: I'll highlight one bucket, but I'll give two examples of it. So the bucket is broadly speaking, trying to understand the role of improved energy access in development outcomes. So I do my work mostly in the developing world and mostly in Africa these days. And the first project under that umbrella is one where we try to adopt what I would call an energy services perspective more than an energy as a binary kind of perspective. So in the binary perspective, you either have clean energy or not, or electricity or not, and it would be measured as this connection that gives you that energy, but in the service perspective, it's okay, what are you now using that energy for? And what are the pathways that we would expect out of that service? So the service that I've focused a lot on recently is cooking because cooking requires a lot of energy.

It can be done with traditional methods, just three stone fire, like your campfire, or it can be done with advanced appliances like electric cookers, gas stoves, those kinds of technologies. And a lot of the focus on clean cooking has really revolved around health impacts for obvious reasons, because these two types of technologies have very different implications for the pollution that they generate in the household and that the cooks are breathing. But in the current project that I'm working on, we're actually focusing on the time aspect of this and trying to understand the time implications of improved cooking, because an underappreciated impact channel from my perspective would be if there are significant time savings, these cooks or fuel collectors can reallocate that time and potentially use it for much more productive things or just to improve their wellbeing. And so in a multi-country study, again for African countries, we're deploying a range of different techniques to measure time use, to measure these time savings, with control groups and treatment groups that get an improved technology.

And then looking at the question of reallocation of time, how do people use that time? Is it for income generation or is it for leisure and what are the implications for wellbeing, which kind of goes beyond some of the traditional aspects that folks have concentrated on with cooking.

And then the second project that I'm really excited about right now is one where we're thinking about renewable technologies supporting agricultural technology change. And so this is things like solar powered pumps that help farmers irrigate or solar cold storage facilities so that you can store your produce. And in a particular evaluation, we're sort of focusing on a pretty innovative new model in Ethiopia, where there will be a mini grid, which is kind of a small grid of solar panels, providing power to a village where the farmers have traditionally relied on diesel pumping and seeing what the implications are for their use of water, for productivity, whether they save money in the long term, and then how this converts into a more vibrant rural economy. So that's again, sort of focused on a different service, but it's sort of agricultural production.

Dean Kelley: But presumably also is less damaging to our climate.

Marc Jeuland: Exactly.

Dean Kelley: Yes. Yeah. Well, it's been great to have a conversation with both of you and it's included both umbrellas and buckets, which I think is very appropriate to the topic of climate change. And I'm grateful for the work that you're doing and it's exciting. And so I really want to encourage you to continue working with the students and it's great that you can engage the students in it as well. So I just want to thank both of you for coming. Kyle Bradbury is managing director of the Energy Data Analytics Lab at the Duke University, Nicholas Institute for Energy, Environment and Sustainability. Marc Jeuland and is a faculty member here at the Sanford School of Public Policy, and also the director of our Energy Access Project. I'll be back soon with another conversation, I'm Judith Kelly.