AI Applications in Energy Can Have Far-Reaching Impacts. Saving Lives May be One of Them, Suggests Nigel Goddard

*Nigel, what made you interested in energy as a computer scientist?*

I've been through a series of areas. I first became interested in energy in terms of the economy. Energy can be thought of as the basis of the economy since it's what we use to process all the materials we use, provide all the services, and run our computers. It’s all energy. Of course, we use money a lot to decide what to do with that energy, but actually, it's the energy that runs things.

I also started thinking about applying machine learning. I think the energy space, like much of the modern world, has become accessible to machine learning because we now have a lot of data. Decades ago, you would design and run an electricity system and get very little data about how it was operating. Nowadays, we can “sensor up” almost anything, and machine learning can then provide you with insights that you might not otherwise get. I mainly focused on domestic energy use, partly due to the various people at Edinburgh that I started talking to about energy.

*When you talk about “sensoring up”, I suppose that energy data from households is more available thanks to the more widespread deployment of smart meters…*

Yeah, I actually ran a big study where we recruited 250 households across Edinburgh and sensored them up to try and figure out what they were actually doing with their energy. The tagline we had for our projects was “putting the smarts in the smart meter”, because smart meters actually aren’t smart at all. [laughs] They just give you a lot of data. The idea was to use the kind of data from smart meters to get insights into what people are doing. There's a specific thing that we worked on quite intensively; it's known as the disaggregation problem in machine learning.

*How does this problem manifest in data from domestic energy use?*

If you're getting readings from the meter at the house that tell you how much electricity is being used, the task is to figure out which appliances are in use. Let's say you're getting them every 10 seconds, which is the smart meter standard. If you can, then with that one sensor, you can infer what's going on. Then, you can give feedback to people on their energy use. Prior to smart meters, you would have had to put a sensor on every appliance. We did some fairly groundbreaking work on that disaggregation problem, and it's had a number of applications.

*The Peoplehood project studied one of the possible applications, aiming to help people with vulnerabilities. How did that project come about?*

It was an idea of Dr Linda Webb, who was at the time a postdoc at the university. She noticed that people who are older or have some vulnerability often will have fairly routine behaviours at home. I always make a cup of tea between 10 and 11 in the morning, that sort of routine. And if that doesn't happen, it can indicate a problem, like a fall or some other medically-related or care-related event. This can be a hint that somebody should go and check on that vulnerable person.

We trialled this in the Peoplehood project, working with a housing association called Blackwood, which focuses on vulnerable older people. In most cases, we didn't use the smart meter data because the system didn't work as advertised. So, we installed our sensors, which were equivalent to smart meters. We ran our algorithms for disaggregation, and they showed the time the shower, kettle, washing machine, etc., was on.

The people gave us rules like this: “Here’s what I usually do. If I haven’t used an appliance by lunchtime, there’s probably a problem”. We then arranged for them to have a responder whom we would try to contact if we detected a problem and the vulnerable person didn’t answer. The responder would decide whether to go and check up on the vulnerable person.

*How did people react to this project?*

We got feedback from about 20 people, and it was very, very positive. It made the people with their families and carers feel more secure. They felt the system would look out for them if something unexpected happened. We actually had one real-life incident where one of the participants had a medical event that caused her to be unable to respond, move or do her normal things. Our system kicked in and tried to contact her but couldn’t. It contacted her responder, who went around and found that she needed medical attention. She was fine in the end, but it was a matter of a few hours from when this thing happened to when the medical attention got to her - if that system hadn't been there, it could have been days. Particularly for people who live in remote areas, it would be something worth trying. We're looking at getting further funding to move beyond this kind of prototype stage to a service that could be commercialised. And potentially, it's the sort of thing the NHS or the council care services could offer.

*How does the system you are describing work in more detail? Can the AI algorithm tell which appliance is being used?*

Yes, that’s exactly it. For something like a kettle, you turn it on, the energy use goes up and stays at a constant level while the kettle is on. When the kettle turns itself off, it goes down. Very simple. If you look at something like a washing machine, when you turn it on, nothing happens at first because it's letting some water in. Then the water heater turns on, so that's a bit like a kettle. Then the water heater turns off, a motor turns on, and it moves your washing around. There’s a whole sequence of things that go on with different bits of the washing machine, so you get this much more complex pattern of electricity use over time.

*How did your algorithms learn these patterns?*

We had to train the neural networks on individual appliances. Then, what we got at the meter was a combination of the patterns of the appliances currently in use. It's all one electricity use, so the patterns added up. The neural networks are actually quite good at detecting the shape of the pattern even when it's mixed up with others. It’s not 100 % reliable, but it's reliable enough to be used in practical applications.

*Will a similar application of machine learning become more widespread, aiming to reduce energy demand?*

We were really getting going with this kind of advice around 2015 and 2016. One of the things that became quite clear to me was that most people didn't want to think about energy. They might have thought about what they do with energy, like: ‘Oh, I need to do the laundry’, or ‘I need to cook’. They didn't want to think about energy usage. With the recent price increases that we've had, people have become a lot more conscious of that. So, yeah, some of this kind of feedback can be useful. In the homes of the future, we’re likely to be able to do some automation where the systems in the house will figure out the most efficient way to complete energy-reliant tasks instead of people.

*In another project, Enhance, you focused on energy use in university buildings and public buildings, such as entertainment venues. What lessons did you learn there?*

A lot of energy use is determined by people's behaviour, not by some system. The systems underneath are what people have to work with, but how they choose to use those systems is what determines the energy use. We developed methods for working with people to try and engage them in coming up with ideas about how to do things more efficiently. At the moment, we are expanding this to a net-zero-directed project. In this area, there are so many stakeholders: energy companies, policymakers, city councils, homeowners, and people who have to commute to get to work. If you don't get them all somehow involved in crafting net zero solutions, people will say: “That doesn't work for me”.

*You said that recent increases in energy prices have contributed to people's increased awareness of their energy usage. Can you generalise the advice your projects provided to the participants? What appliances enable the biggest energy reductions?*

People think that because the light is bright, it must use a lot of energy. Whereas, as engineers know, energy really goes to heating and cooling. We gave every household a tablet, and we designed an interface for them to look at how their energy was being used. We would give them suggestions on, for example, what sort of wash cycles they were using in their washing machine and suggest to them that perhaps they didn't need to run at such a high temperature, or if they weren't spinning, that it's a lot cheaper to spin the water out of the clothes than it is to tumble dry it out.

*You are one of several scientists at the School of Informatics interested in energy. What other energy-related projects do computer scientists work on?*

Some are using machine learning methods in robotics, looking at autonomous or semi-autonomous drones to monitor power lines, for example. Monitoring the condition of transmission power lines is important. You can't put sensors everywhere, so a drone that can just fly up and take close-up pictures, give you video, and possibly even sense how hot the wire is getting would be ideal. If you run a drone like that, you don't want people to have to fly it. It’s best if you can automate it.

*I was very intrigued by your mention of energy as the basis of economics. If I am right, this idea led you to use dynamic modelling to account for our economies’ biophysical constraints. Can you tell me more about this research and how it fits within the limits of traditional economic thinking?*

We use system dynamics models to try to create a model of the economy, thinking of it not as a financial system but as a biophysical system where materials flow in, being transformed with energy into products and services. It’s very different from the economic way of modelling, which is to do everything in terms of prices and money. The system dynamics models allow us to model time processes. If you want to build a lot of wind turbines because you decide to use renewable energy, that takes a long time because it's a physical engineering problem. System dynamics models allow us to model processes that economic models don't. I worked on this with some people at Arup and Brunel, looking at the UK's net zero policies.

*What suggestions did you come up with?*

One key point was that if we build all these wind turbines and put them in the ocean, we need a lot of equipment. You don't just need the factories; you also need the ships to transport them, the various machines that will install them on the seabed, and so on. That wasn't really factored in when we did this.

*What project are you currently most excited about?*

I'm getting back into the system dynamics modelling. I'm most excited about using these models as tools for policymakers to test their ideas. Suppose we go hell for leather for some particular hydrogen application; how will that work out? What effect does that have on other parts of the system? Economists have their way of doing that, and that has its value. But this biophysical modelling has its value, too, because it shows up other constraints. The advantage of these system dynamics models is you can model complex interacting systems, and then you see that making an intervention in one place has an effect somewhere completely different. You might not anticipate that ahead of time.

*You are involved in Energy@Edinburgh; what value do you see in networks like this one?*

The biggest value of this kind of network is its interdisciplinarity. If I want to build the kind of models I was talking about, I need to include some of the social and organisational aspects. But I also need engineering expertise to understand what actually goes into building and using wind turbines. So, I need to bring those together. Having a network like Energy at Edinburgh, where people are already talking together, is great; it’s perfect.

*If people want to start with dynamic modelling in energy but are unsure how to do so, what would you advise? Where can they start?*

Well, I just started teaching a course for people across disciplines. The course is on computational modelling of systems for sustainability, and we use system dynamics modelling. There are some very good examples of large-scale global dynamics models. A classic one was built in the 1970s, called the Limits to Growth, and became quite a political football. But the work has been carried on and updated. Most recently, there's an EU project called Locomotion that has built a global big system dynamics model that's looking at the net zero transition. That's a place I recommend people start. In terms of languages, we use a system called NetLogo, which is designed for agent-based modelling but has system dynamics modelling. Those two modelling approaches complement each other. NetLogo doesn't require complicated programming expertise, so social scientists can use it and understand what it's doing. So, if you want to get into this kind of stuff, it's worth looking at both. And they're very different to the optimisation models that many engineers and economists use. If you have programming expertise, there are more sophisticated modelling packages, typically based on Python. If you're trying to build a large-scale model, that would be a good way to go. And in the case of system dynamics modelling, there are commercial packages. Vensim is very widely used, but I don't use it myself.

*Let’s move on to the last question. What keeps you motivated as a researcher? What do you see as your main goal?*

Well, it's evolved over time. But at this point, what I'm really trying to do is to bring an appreciation of the complexity of the systems that we live in and rely upon in the world, how they interact, and that there aren't simple answers. A solution that you produce in one place may have some negative effects somewhere else, and that's just the way these systems work. The purpose of the course that I'm teaching is to try to give undergraduates a sense of that. It’s the sort of thing I would like to bring to policymakers. When I see some policies that have been produced, they're often very simplistic and don't address the complexities of the problems that we're facing. I think we're in a different time now than we have been. We’ve been trying to change and optimise things slowly. We're now at a stage where we have to upend many things at once, and we don't have the expertise or the tools to do that. It's not something that's taught. And I think this kind of modelling method can be the basis for some of this complex transition.

*Thank you so much for this interview.*

Okay!