Optimising investment for a low-carbon future

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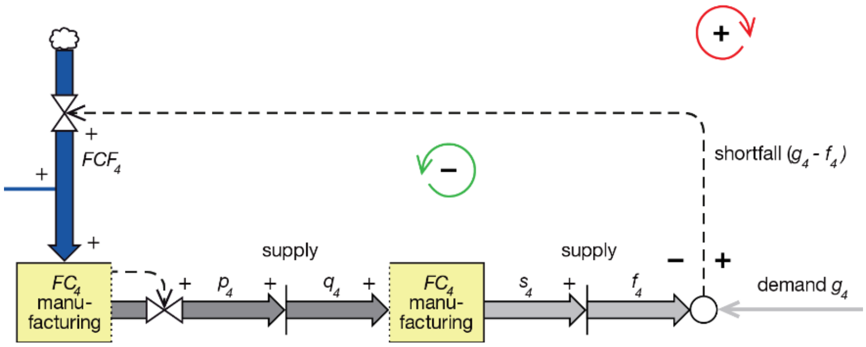

Colin Axon

[a] 1/18 We are both interested in is the energy use within the economy; that's our starting point. We're both physicists, we're both practicing as engineers; we are thinking about infrastructure and energy use in the economy.

But to do that we've got to actually understand what the economy is doing. So the question we were trying answer is something along the lines of how much can an economy afford in order to go low carbon. The Government suggests it's desirable to move to a much lower carbon intensity of power production and therefore we have got to move away from the system we currently have.

The whole thing about energy systems, is if you're on holiday in Ireland and you're somewhere in the countryside and you say to someone how do I get to Dublin and the response is, “Well, I wouldn’t start from here.” The trouble is, we are starting from here, we have to adapt and move from the system we currently have, both in terms of what the economy is and does, and in terms of the energy system and how it is structured.

That's the premise of what we're doing. Our modelling philosophy is to find a simpler set of rules that mimic observable behaviour.

2/18 We start with the infrastructure, the physicality of the economy. There is stuff in the economy, there are people in the economy, there's energy in the economy. These interact in some way, moving from the physicality of the infrastructure, in the end goods turn into services, an example being retail. Objects are made or grown, they are supplied and they meet some sort of demand from consumers.

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[a] Cross reference to PowerPoint show by slide number and total number of slides.

The best data possible for this is the GDP data and the national accounts on which it is based. The national accounts are a dataset which tells you, or estimates, how much activity has been exchanged between, something like a 100 different industries or sectors. You can use that and you start to think about how do you model that, how do you mimic what is going on there. There's a dataset for every year, going back however far.

We then want to fuse that dataset with population - understanding population dynamics - energy data, import, export, transport data, etc. All of these come together and are this thing we call the economy.

3/18 This is a snapshot in 2014 of the whole of the UK economy, all on one picture. Obviously it's not very detailed but there are some interesting features.

This is a called a Sankey Diagram. If you've not come across them before, the rule is that the width of the lines is proportionate to the size of whatever that flow represented. We're looking at the movement of stuff through the economy. So we've got people, jobs, we've got various energy flows, coal, gas etc., some of that's turned into electricity. We've got transport, and some of it's used by us of course, but some of it moves stuff around.

We've managed to aggregate the economy’s 80 or 100 units, separate units into seven, hence our model is called 7see, seven socioeconomic energy sectors. We've got manufacturing, construction and services. As you can see here there is an awful lot of activity involving services, that doesn't come as a surprise, but there are interactions between all of them.

This middle part is called intermediate consumption; that is business-to-business transactions of unfinished goods exchanged between companies to produce the final set of finished goods or services that will meet the final demand from household consumers. Some go to exports, some are Government services to consumers, some to the third (charity) sector, and most to household consumption. The question is, how do all these businesses in these sectors and in these industries keep themselves going, how do they maintain their assets, how do they build infrastructure, how do they build their businesses.

Well, essentially what is happening is that there is some portion diverted into this blue line, which follows back around and goes as to all the boxes. They represent the formation of fixed capital - fixed capital being assets, stuff that lasts longer than a year, machines, factories, offices, etc. It is fixed capital that allows businesses to operate in such a way that they can meet the demand from consumers.

So, that's a very quick snapshot, that represents one year on aggregate. You can obviously build those up for a number of years. But that's not dynamic, so how do we make it dynamic? Following our philosophy of a simple set of rules that mimic observable behaviour, we want a small number of feedback loops.

4/18 For example, this is one of the industries, manufacturing. There's supply progressing from the left. Demand from the right has to be met and has to be matched. If there is more demand than supply, you've got to increase the supply somehow. That we implement as a negative feedback loop: not enough supply to meet demand, turn the tap on, increase the supply. Demand for fixed capital formation (FCF) looping across the top turns out to be a positive feedback loop, so there's a tension between these two.

Each of these industries has not only one of these feedback loops to meet its demand, of course, but they are exchanging demand between the different industries as well. So there's lots of things going on, hence System Dynamics turns out to be quite a good way of looking at this, or at least is a good tool for making this work.

5/18 This is a skeleton of the model. You'll notice some of the same types of symbols here indicating we are really doing System Dynamics. Demand is from the right progressing left. Supply is comes from the left, going to the right. Where they meet and are reconciled is at these blobs. Every time there is more demand than supply, something gets turned on to try and meet that supply, okay, and that means building a bit of assets.

6/18 So coming back to this question of how much can we afford. Well, the blue line that you saw on the first Sankey Diagram is this one. It's made up of all these industries contributions which we merge for clarity in the diagram. The thick blue line as it stands is meeting the current needs for asset renewal.

If you want to increase – you want to build extra assets that we don't currently have such as wind turbines, nuclear power stations, pick what you like –you've got to increase the width of this blue line somehow. In practice what we're doing is diverting some household consumption in order to meet this new demand for fixed capital formation (the formation of assets).

So the answer to our question is here: the extra bit that we need to produce is clearly much thinner than the current amount of fixed capital formation. To build lots of wind turbines to try and go low carbon, etc, actually we don't need a great deal of extra investment.

We need some, but it's very small compared to what we already do. We'll come back to that. Why it's the answer is more interesting. In the next two graphs we've got it set up to show you the effects on the economy, okay, that's more interesting. Finding the answer to how much we'll spend is not that difficult nor that interesting. However, what it does to the economy is...

7/18 This is jobs, the discreet blobs, on whichever line, they are real data. Our model is the solid line that we hope matches in some fashion the real data or is at least plausibly realistic. The solid lines continue as projections. We'll show you what the effect is of increasing this investment to try and have some sort of low carbon transition. We'll come back to that graph later on.

8/18 So here's for me the crux. I'm an energy system researcher really, and, you know, the crux of everything we do is carbon emission in the economy. Again, discreet blobs are the real data and the line is a projection based on a genuine business-as-usual scenario. We'll say something about business as usual later; what we mean by business as usual, since most people have only a reference case and not a true business as usual.

You can put a ruler through these lines and they're heading down. Okay, it's been going down historically, that seems to be good. That's because we've been picking off all these relatively low-hanging fruit in terms of becoming more energy efficient, etc [and the 'dash for gas']. The projection is that actually this is going too slow, because we've done most of the easy stuff. That flattening off is obviously undesirable, we don't want that, because the Government's 80% reduction target is this green circle. If we had carried on how we have historically, we were never going to meet that, and at the moment we are heading in the wrong direction. How on earth are we going to meet this, how are we going to make this work? That's what Simon's going to tell you.

Simon Roberts

9/18 Picking an approach to how we go to low carbon, there's some work by the Committee on Climate Change. They publish carbon budgets. The most recent is the fifth carbon budget, which is brought before Parliament and they vote whether to comply with it or not.

It has a rich set of measures, which have been put into this model. Instead of looking at all of them I'm going to pick on just one component, which is related to electricity generation. The fifth carbon budget has majored on carbon capture and sequestration, but many people feel that that's not actually going to be very successful. I'm going to show a couple of others, which I'll indicate by the schematic here, in order to show how the methodology can make a comparison between them and thus help in the decision of which to pursue. And therefore to show what benefit there is by this modelling.

Now in order to make a comparison between them the first step is to set up a realistic business as usual, which Colin has been showing you. Most other analyses tend to have something called a counterfactual or reference and don't purport for that to be a business as usual. It's actually quite difficult to find anyone who really tries to do a business as usual.

Business as usual is within the model here. It is based on calibration from, as you've seen, 25 years of historical data. This data base is the basis of a rich methodology for going forward, all based on System Dynamics. It's certainly not straight lines with rulers.

The first thing is to have the business-as-usual context. The next thing in making a comparison is between the technologies, and this is what the schematic is showing.

The first shows schematically how CO_2 is captured from a smokestack of coal or gas fired power station and put in the ground; that's called carbon capture and sequestration or CCS. The next one is for even more nuclear. There's been a lot of discussion about Hinckley Point. There is a school of thought that says let's decarbonise the grid by going more nuclear, and that's plausible. Finally there's more emphasis on offshore wind, which has also got supporters. I will use the model to make comparisons being made between them.

The next step is to find out what good work has been done: some engineering and, to some extent, economic analyses to figure out what are plausible rates of growth. So, not a hand-waving one, but projects that have been substantiated.

The Committee on Climate Change does do a lot of background work and they've got a proposition for CCS. For the nuclear one, the Committee on Climate Change has got one projection. There's another one that the Government has talked about, called the Nuclear Pipeline. There's a good piece of work done by BVG Associates to look at what's a plausible fastest rate of growth for offshore wind. Step number 2 is taking their work and bringing it into the model. They enable three scenarios which can be inspected and compared, as I'm going to show you.

Question Excuse me, is there a reason why solar and tidal lagoons, for instance, have been excluded in that?

SR Okay, well, solar is included already, there's not great scope to expand it, but it definitely could be put in there. And equally the tidal lagoons, though these have even less scope for major expansion. The reason for picking the three I've shown is you can actually see their impact on the graph; they're big enough to make a difference.

There's no reason why other renewables can't be put in. Actually more the better approach is a policy set, tweaking all the levers. If one does a bit more transition to electric vehicles, a bit more of this, a bit more of that, they together would be a representative policy. Then to examine the overall cost and systemic consequences to the economy.

So we're just showing three here, more for illustration, but they are the big ones and they're also very topical, if you're involved in energy as we are.

10/18 First of all to look at what the proposition is by the Committee on Climate Change for CCS. On the left is the capacity of coal fired power stations, which as you see historically has been dropping rapidly and they're due to be phased out completely by the early 20s when we'll not be burning any more coal. So the proposition here is to increase the capacity, together with CCS. So in effect have carbon-controlled coal-fired power stations.

On the right it's the other way around. This is gas combined cycle turbines, the power stations. As Colin as shown, their lower emissions compared to coal has been described as the dash for gas. The starting point happens to be 1990 – the start of our historical data period. It was in the 90s when it really took off following deregulation of the electricity industry. Capacity has been climbing up until recent years.

Now within the model, Colin showed you on the Sankey diagram which has lots of different colours. There is a different colour for each flow, each of which has a feedback loop. For the flow of electricity from generators to users, we use gas fired power stations as the one element that reconciles supply with electricity demand. The line passing through dots is the model to reproducing historical data of gas generation capacity.

With the business-as-usual scenario, this is the top line. In the fifth carbon budget, together with CCS, these are the two lines coming down. The fifth carbon budget reduces demand overall though gas CCT is still replacing the remaining coal-fired power stations. The CCS is proposing some of the gas CCT has carbon capture.

So this gives you some idea of the projections. The point about this is they're over time. You don't just pick a number but a plan over time that can be implemented.

11/18 For nuclear, you can see the historical period of progressive closures down to the bottom line. Sizewell B, being the most recently built, will by 2030 would be the only power station left.

You've heard about Hinkley Point C, that's currently being built. This is the next line up from the bottom. This line drops as a different power station is closed. We end up with just over 4 GW capacity of the power stations: the new ones and the existing one of Sizewell B.

Sizewell C might be another plausible one shown. The one for your attention is the dashed line corresponding to the fifth carbon budget, that's what they're proposing, quite a significant proportion. For our nuclear scenario, the top curve shows an even higher rate of expansion. It's related to something called the Nuclear Pipeline which Minister for Energy, Andrea Leadsom, gave a speech on last year. (It is about the strongest Government statement I could find as to what might be a possible growth path for nuclear.)

12/18 What makes nuclear very different is it takes a long time to build. The Sankey diagram is a snapshot corresponding to one year. Over a year it shows the resources out of the economy that go back in to build infrastructure; the blue line over the top.

Each power station takes many years, so within the model we consider the diversion of resources to build over a substantial period before the station is commissioned and supplying power. I have picked a set of power stations, phased in time for their construction. The envelope is the call off of resource from the economy. This contrasts with talking about an average price of electricity over the duration of use. This is talking about the year-on-year diversion of resources from the economy before each station comes online. This makes it different from the off-shore wind and carbon capture, which basically commission within a year of building effectively. We don't need to worry about a time delay.

Another point is that although the scenarios are going to 2035, you won't stop building nuclear power stations. The Pipeline proposition is for further commissioning beyond 2035 which requires spending before 2035.

13/18 The last one for offshore wind is a simple picture. You can see historically it's been growing and becoming more important. The business as usual simply extrapolates what has been accomplished recently: if we've managed building at that rate per year then we could just carry on the same rate. The fifth carbon budget is an accelerated rate.

BVG Associates have examined what might be possible for the North Sea to grow, from which this fastest growth is taken.

Colin Axon

14/18 We come back to the costs in terms of the fixed capital. Taking account of all these possible build rates, the delays, this is what it turns out as. We run the model to 2035 because we keep it as a fulcrum between the historical data we have and how far we project. We think that's a plausible way of doing it.

So it turns out that CCS is jolly expensive. It needs a lot of capital. (Ask me afterwards if you really want me to talk about why I think CCS is a very poor option.) Nuclear is also expensive, but much less so, and wind is by far the cheapest way to go.

The important thing as far as the climate is concerned is not so much the rate of CO_2 emissions, but the cumulative amount, because the residence time of CO_2 in the atmosphere is something like 80 years. It's cumulative carbon that's important. This is where the delay in building or the length of time it takes to build a nuclear station becomes important. You're sinking lots and lots of concrete, you're using lots of assets, but you're not getting any CO_2 reduction payback for a long time. Therefore the building of nuclear takes a long time to catch up, and that's really important if you're interested in what the climate's doing. Wind and CCS are quicker to build, even though the costs are quite different. These are some things that actually are overlooked in a lot of the analyses and discussions, and certainly in policy terms are overlooked.

15/18 Here's the answer to those two graphs I showed right up front. So what actually happens. Let's stick with the CO_2 emissions. Here we have our business as usual: if we carry on doing what we're doing that's where we'll end up, we'll level off, not good. All the scenarios do bring down CO_2, but nuclear less rapidly in CO_2 terms as the other two.

In terms of fixed capital formation you can see historically the range of values. Business as usual is the dashed line going forwards. A thing to notice is that all the scenarios require extra fixed capital, however not much higher than in 2007 just before we went into the financial crash. These scenarios are really not much above that. So in terms of what impact you might think this would have on the economy or how it could affect day-to-day lives, actually it's not that great. It really is affordable, regardless of what anyone else says, it is affordable.

So what about jobs, because there’s no point in going low carbon if it makes everyone unemployed. No politician's ever going to sanction such a policy. So what effect does it have? Well, service industry jobs still grow. The low carbon make a difference but it’s very small. Manufacturing's the same. The one that is most interesting is construction, as you would expect; you need people to build these assets.

So there's a boost to the construction. This falls out of the model. It is an economic model in that sense, or it's a data model really, but we can model unemployment in it, which is one of our key points that we like [about the 7see model].

Go back to emissions on the left, the thing to notice here is that we stop at 2035, but as you can see we're still not necessarily on the trajectory to reach the 2050 reduction target. This is tough, really tough, but we can do a lot, lot better than we are now with not much pain at all.

16/18 Here’s what we would like you to take away from today.

We've got an interesting model that uses the best data available. It uses a simple set of rules, which mimic and model what the economy has been doing. We can model unemployment, that's really hard actually, and more or less nobody else does that.

The UK's national accounts obey the international set of rules that every nation obeys in terms of how it structures its national accounting mechanisms. Because we comply with that our model can be used for any nation you choose. Simon has done work on Australia, Colombia, which was very interesting, and Taiwan and he's recently started on the US as well. So that's all very interesting, it's flexible, and we want to roll that out. The other thing is this proper business as usual case; what actually happens to the economy as it goes on.

17/18 That's a lot of information, there's a lot to unpack there, but it's not just us two, as much as we'd like to take the credit for all that. We've had three collaborators helping develop the model and this is a global effort. And we've had a number of people really pick apart the scenarios and test their plausibility, both economists and people interested in international development and energy specialists. We all are satisfied that we've got something that is genuinely plausible.

18/18 We've rushed through this, it's a massive model, there's lots to pick apart, lots that can be done, lots that we will do. Of what we have done so far, there's a whole bunch of resources that you can pick up and we'll happily send you. There's, as Simon said, the “What is GDP..?” booklet, which is jolly good, because most people - probably most economists - don't understand what GDP actually is. This tells you in a very nice simple straightforward way. Also very good for students if anyone's teaching in universities.

There's a White Paper that we produced and we've got a journal papers where we've exposed the model to peer review. We felt that that was important too, which is one of the things that actually very few big macroeconomic models do. Historically they've not been willing to expose themselves to peer review in quite the same way that we have, but we felt that was important.

So we'll happily take your questions now. Thank you very much.

Question 1

Your focus is on, or what I've heard what you're talking about, is the means of producing energy. Did you also model possible changes in demand; ways of impacting on demand?

Simon Roberts

Absolutely. In the framework, the boxes represent infrastructure. For example, a power station, a building like this we’re in and dwellings. These are each end of the line. The start of the line is the generation, of which we’ve shown you examples, but equally important is the other end. That end is certainly modelled covering demand related to the activity of the infrastructure. In the case of the services industry, the demand for electricity is related to the output of services. For dwellings it's related to the number of dwellings. The point about these relationships is that they evolve with a time. Generally they're using less energy per unit of output and it appears that these downward trends fit a decay curve down to an asymptote.

That's part of how we develop the business as usual. The relationships between an entity, such as a building like this, and its demand for electricity. All the demand for electricity is aggregated, as is the types of generation. Then they're reconciled and something has to be adjusted to ensure they equalise.

Question 2

It's the first time I've come and it's only thanks to Steve, in fact I've learned about all this. An absolutely fascinating paper. I've never seen a representation like this before and it's an excellent presentation, congratulations.

Just one. I'm not an engineer or a mathematician. I'm an economist by background, but of one of the things that occurs to me, and it's not a serious criticism on you, because I think it's very, very difficult, is, if I understood correctly, are you implicitly assuming that relative prices of various commodities are not going to be changing at all? Because that could have quite an influence.

Also is this going to be, say, taxes to account for externalities? I mean, there's always a call, isn't there, for, well particularly economists with emissions, for example, created by aircraft, for example, and of course the aircraft industry resists all this. So in the light of what's, one doesn't know what's going to happen there, have you been forced to assume the relative prices of various commodities in your economic model or have you actually experimented with the differences, taking into account possible changes in environmental taxes and so forth?

Simon Roberts

Both of those are definitely there. First of all, the data to quantify economic activity comes under GDP. Included in the analysis of GDP is what's called the GDP deflator or inflation. This enables GDP to refer to *real* growth of GDP. This is one aspect of national accounts is to derive the GDP deflator and in order to get to a comparable quantity over time.

As it happens, you can't use the same deflator for fixed capital, because they're a different mix of goods and services compared to overall consumption. That's the first part.

With imports especially a step change of currency exchange would have an impact. For simplicity we use the same deflator. If imports are going to be significant and there's going to be a price change, then it would need a different approach to be covering that one properly, I have to say.

And then your last part is to do with taxation. In fact the Sankey diagrams representing the components of national accounts start with what's it called, gross value added (GVA) of each industry. The accounts separate out what's called taxes on products, what we pay for. Our model takes account of the flow to taxes but not any influence they might have on demand. Including taxes ensures the numbers are consistent from industry output through to final demand. Looking at changes over time, the tax ratios hardly change, within the scale of line thicknesses in the Sankey diagrams. The tax added is very small and it's more to do with how the metrics are quantified. We're not using taxes to manipulate demand.

In contrast to a typical economist’s approach, we’re not seeking to say where the money goes, that's quite a different concept. It's a completely different exercise to what we’re doing to say, amounts of money go into different places and are multiplying debt and so on. Here we are using national accounts to put a fixed number on the amount of stuff, whether that's called services, curious stuff, or goods or whatever. The tax in there more just to achieve a balance of the lines.

Question 3

I'm quite interested, and I'm also an engineer, and I also have a special interest in energy. This question was raised earlier on when you were actually giving your speech, in respect of you said that you didn't take hydro into it account or solar, I'm just wondering then what would have been the effect if you had actually considered all the options of renewable energy.

Colin Axon

As Simon said, the model contains all of these. This is for the UK, so as it happens there are basically no more hydro sites in the UK, so that's essentially fixed, unless we're willing to start flooding some more of Wales. I don't think the inhabitants will be too happy about that, but that is possible. So for that we can tweak it a little bit. Solar, yes, it can grow and it will grow. It's in the model, but actually it's really small compared to all the others.

Bio. It really is never going to have that big an effect. It's a question of what makes the difference.

Simon Roberts

I think just to continue on that and what's in this analysis already, it is what comes in the fifth carbon budget. This is reasonably ambitious for more PV and more on-shore wind. Those potential for further increase.

More of a challenge is clearly the demand. Demand is very much in the model but there are few measures in the fifth carbon budget. For instance talking about the demand in this room. That's a much more difficult challenge to reduce through national policy or regulation or whatever. To make the emissions line come down faster and keep on that trajectory, it needs a huge change to do the demand side.

Question 4

I've got one, a general question and it relates to a specific as well, and that is, where in the model are assumptions about technology driven cost production? So things become cheaper over time, so the low-hanging fruit that you say we already took, well there are more low-hanging fruit than when we started taking them, because things have got cheaper.

That's already started to happen to some significant extent with solar, but we are way back at the beginning of that experience with power storage. So power storage is now just about economical to install in your home. You shift your demand from when electricity is expensive to generate, in the morning, in the afternoon, to when it's cheap, in the middle of the night, when the wind blows and in the middle of the day when the sun shines. So where, do you have a model that attaches power storage to renewables and recognises the probably very rapid reduction in power storage unit cost that's going to happen over the next decade or so?

Simon Roberts

The first point relates to the learning function and the cost reduction. That's in there. It depends on what rate at which the cost per megawatt capacity is going to be going forward. For off-shore wind, a plausible reduction rate was put in. Less easy for nuclear, which turns out to be more expensive. Different learning function rates one can put in different scenarios.

To do with the storage, the thing is that it doesn't actually generate. I think the main point is when there is a high degree of penetration of intermittent renewables when the additional cost of storage is necessary for their viability. When the cost of storage is added it can also be on the basis of decreasing cost over time.

We can put these parts together very easily, these varying time curves, and compare in different scenarios.