AEMC

TRANSMISSION ACCESS REFORM
PUBLIC FORUM EDITED TRANSCRIPT

Simplified model of the reforms in action
Tuesday, 22 September 2020

Introduction and admin

MS MOLLARD: Welcome everyone to our second public forum on transmission access reform. Many thanks to those of you who joined us last week and then are also joining us today. Really appreciate you taking the time to do that. I know most of you are on the call but for those who don't know me, I'm Victoria Mollard and I look after our security and the reliability team here at the Commission, of which transmission access reform falls within.

Today's forum is intended to provide you with an opportunity to engage on our simplified model of how transmission access reform would work, which is something we have developed in response to stakeholder feedback for something that was a bit more real world and something that you can all play with in terms of how it works. So, I'll just quickly introduce you to everyone on the call from the AEMC side. We're lucky enough to be joined by two of our Commissioners, Charles Popple and Michelle Shepherd. They're both here today and will be making some remarks as we go throughout this afternoon.

We've also got the COGATI team on the call. Many of you will know them, Ben Davis, Russell Pendlebury, Daniela Moraes, Tom Walker, James Tyrrell, Jessica Scranton, Orrie Johan and Tom Meares. And then we're also very lucky to be joined by some of our NERA colleagues, who thanks again, an extra special thanks to them for either getting up very early, if they're based in the UK, or staying up late if they're based in New Zealand. Thanks to NERA again for being here with us today. I would also like to say a big thank you to everyone here in the forum. We've had a lot of registrations and it's great to see there's so much interest with a really wide variety of people here.

I know there is a lot on at the moment, a lot of briefings going on this week, so we definitely really appreciate your engagement and taking the time to be here today. I'll just quickly talk through the agenda. So, as I mentioned, we'll shortly hear from Charles Popple, one of our Commissioners. We'll then here from Ben Davis, who's the project sponsor for the reform, to talk about what we asked NERA to do. And then we'll then hand over to NERA who will talk us through the model, how it works

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and the various scenarios and there's going to be lots of opportunities to ask questions and comments throughout.

When we sent out the invitation for this forum it would have had a link to download the model itself, so you can all plan along at home as we go through this afternoon. And then finally I'll hand to Michelle, who will close us and talk a little bit about next steps. So, before we get into that, it's just worth covering off on some logistics and housekeeping. As we said, we're very lucky to have the NERA team here today who developed the model, so it's a really great opportunity to ask NERA questions. We're hoping most of the time will be questions and answers, so please feel free to make comments or ask questions by the Q&A function which you should see down the bottom of your screen.

We ask that if you could please make comments, indicate whether you're asking a question and then add your remarks. And if you could include your name and organisation at the end that's really helpful for us. We know that a lot of you have a lot of other questions to do with this project and the proposal that we've put in place and suggested through our interim report. We've definitely heard a lot of questions throughout the briefings that we've done so far and the emails that we've received prior to the forum. This question is about what exactly does a simultaneous feasibility test look like. What do you think the impact on financing will be? And lots of questions around NERA's modelling on the benefits of this reform, and the NEM itself. Like what happens if you choose different gas prices.

They're all really great questions and ones we'll continue to chat to you about but given there's going to be so many other opportunities to provide thoughts into those matters, I would really ask you to bear that today's focus is on the simplified model. And bear that in mind and try and focus questions on this aspect so we can get the most out of the session. Where possible if people want to make a comment that's a bit more extensive than you can type into the question box, we can allow for that as well. So, if you prefer just to make a comment, please just write that in the box.

When we get to each of the Q&A sections, I'll be moderating them. And if we think that's appropriate, we can then take you off mic at that point in time and get you to make your comment or ask your question directly to NERA. So that opportunity is available as well. We're going to try and answer all of the questions in this session but if we don't get answers to each of the questions then we'll follow up after the event. So either through a follow up meeting, an email, as you would have seen from last week's session, there were a number of questions that we didn't get to for

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the NERA modelling last Thursday we are going to put up a frequently asked question on our website next week which goes through a lot of the questions that were unanswered from last week. So, we'll be able to do the same with this one today.

As with last Thursday, we're also recording this meeting and we'll publish a transcript and the presentation materials on our website. As I said that will happen next week, so next week on the AEMC's website you'll be able to see the transcripts from both of the public forums. One last Thursday on NERA's modelling of benefits and then the one from today on the simplified model, as well as both slide packs, as well as the simplified model and answers any unanswered questions from today. So that's how we're proposing to run it.

And I can just see there's a couple of questions coming through. I will follow that up in terms of Belinda has said that the email this morning didn't include the model, so we'll make sure that gets out to you Belinda separately. If anyone else has that issue, please let us know and we can arrange that to go out through the process, as we get started on the session today.

So, without further ado, I'm going to hand over to Charles, who's going to make some introductory remarks before we get into the session. Thanks Charles.

Opening remarks by Charles Popple

MR POPPLE: Thanks very much Victoria. And welcome to everyone this afternoon. As Victoria's already said it's great to have you here, great to have you contributing to this workshop today and in fact, we not only value your input, we really need your input to progress this really important work. As you're aware, transmission reform is one of the key market design initiatives of the ESB's post-2025 work and we've been working on this for a little while. It's really about adapting a grid for a new tech energy future, to incorporate renewables and storage in a way that stands the test of time and moves on from the current arrangements that we have, to ensure that the power system remains reliable and secure in the future.

And to assist and allow the connection of new renewable generation into the market and in that way as well dealing with reducing emissions as well. It's an important reform, it's a key reform but it's worth pursuing. And independent modelling is showing that we are saving customers potentially around six billion dollars directly to customers over the next couple of decades by pursuing a reform like this one. And for that reason

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alone it's worth thinking seriously about how we could implement this in a way that brings that value to bear. We recognise it's a significant review of the current market. It's a rethink of the way price signals are provided to new investors in generation, and existing generation for that matter.

Giving sharper incentives for location decisions, for new batteries and for all the new technologies that may come to the grid in the future. We recognise it's a new thing for Australia, access reform that we're proposing is different, but it is a reform that has been implemented successfully and has been operating successfully throughout the world, throughout northern America and of course in New Zealand, our neighbouring country. There's many, many implementations where this has been successfully implemented.

We see a long-term solution here for the transmission system, working for everyone, having two components. The planning and the building of the new transmission is as outlined in the ISP, the integrated system plan. It's an important component for defining the future development of the network. But as part of that access reform it's also key to ensure that the transmission lines that are built are used effectively and most efficiently and provide the value for those customers who are actually funding that development. We've had lots of comments about timetable and the need to be doing this now. We think achieving a workable timetable for future proofing the grid means that decisions are required now on transmission access reform. For all of you that have been part of this journey along the time that the NEM has been operating, you know how long it takes to implement change and you know how long it takes and how important it is to get it right.

But it's also critical to provide some signals about the future direction, to provide that certainty in the longer term. And for that reason, we think it's important to be progressing and developing these changes now. We can't park the forward-thinking agenda just to deal with the short-term concerns. And we acknowledge the short-term concerns that need to be dealt with. And these can be dealt with, but in parallel. We think we need to start planning for access reform now, to provide that longer-term pathway. And if you actually think about it, the need to do short-term fixes often arises because that long-term thinking hasn't been done in time to develop a measured and sensible transition arrangement, which is really what we're seeking here.

As I said before, it's great to see so many of you here today. Well, actually I can't see you, that's one of the challenges of this virtual world, of sort of speaking to a blank screen but I know you don't have blank minds and I know you're bringing a lot of insightful thinking and comments to the table

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today and we really appreciate that. It's an essential part of our decision-making processes and that's why we've had a lot of these avenues for engagement: public forums, submissions, consultation papers, workshop, technical working groups are all part of the way in which we want to engage with you to get your feedback and input.

We do listen and we do understand that there are diverse perspectives on these important topics, and we do want to remain objective and understand your views. That's been particularly important in our transmission access reform project to date and we commit to continuing that process of getting your input, understanding the issues of concern to you, and dealing with them in their responses and in the development of the models. We think today is an example of that, we've listened to feedback, we've tried to develop a model which perhaps in some ways is viewed as being a simpler model, but more importantly, today, NERA have developed a model that lets you play with what we're thinking about to get an understanding, a better understanding of how this essential reform will work on a day to day basis.

Provide the opportunity to ask questions about the operation of LMP and FTRs, both of AEMC staff and NERA, and help - and we would encourage you to feedback those question to us. As I said, NERA is part of the work modelling the benefits of this reform, has built this simplified model of the transmission network, in order to demonstrate how LMPs are calculated, how VWAP is calculated, how FTRs might work, and to just give you the opportunity to tinker and see how it all works. And I don't think there's anything like having a model available to help that understanding, we think that's a really key part of this process and hopefully today, will facilitate your understanding of the model and give you a bit more insight. So, on that basis we certainly hope that you find this session as useful.

Again, I'd reiterate how much we appreciate you making the time to attend and participate in this consultation process. I'd also of course, like to thank NERA for the work that they've done and as Victoria's mentioned, the time they're getting up or going to bed, or whatever it is to attend these sessions today, and also for the AEMC staff. There were many people throughout the AEMC that have devoted some time and effort into this project and for their efforts in consult and consultation, we're very thankful as well. So, look I'll leave it at that at the moment. I'll hand over now to Ben Davis, who will introduce the session. I encourage you all to participate actively. I'm sure you will. And we hope that you find this session today useful. So, thank you very much.

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Introduction of the work done by NERA

MR DAVIS: So as Victoria said, I'm the project sponsor on the access reforms and I think this public forum in particular is really useful because having only come onto the project a month or so ago, I think having a model to play around with and really get your head around the reforms and be able to put in different inputs is really useful for understanding it, particularly as some of these reforms are reasonably large changes to the status quo and do have some complexities involved in them. So, with that in mind, we asked NERA to develop a simplified model of the reforms in action, illustrating how specific parts of the reforms operate and how they impact different participants in different ways.

We really tried to balance the level of complexity in here but with getting enough information in there, so that the model can be meaningful to different parties. And they've made it publicly available to download, scrutinise, understand, and put in different inputs. The team's had quite a lot of fun playing around with the model and putting in different scenarios. In fact, we even tested some of our different design options within the model and find that very useful for exploring how it interacts and I'd encourage you to do that. I think there's a range of scenarios that Michael and George are going to run through today, but also you can use the randomiser button to start off with different scenarios.

So, I think we find that really useful and we'd appreciate your feedback on it. With that in mind, I will pass over to NERA. I think there's just a couple of more admin things to go through. I think we've got a couple of questions about didn't receive - the model wasn't in the email. I think it's in the links at the registration page if anyone wants it. Although I'd probably encourage you to just watch along for today, because you'll be able to see Michael run through it on screen. I don't think you actually need to have downloaded the model. It will probably be harder if you try and do that right now, rather than watching along. So, on that basis, I might hand over, and I also think we're going to switch who's driving the slides. So over to you Michael and George.

Presentation by NERA on simplified model concept andQ&A

MR ANSTEY: I'm George Anstey. I'm a director at NERA in London. Today we're just going to take you through the simplified model first in just sort of concept, what are we trying to achieve and then subsequently we're going to take you through six sort of live scenarios and during that process, Mike who's the consultant in our team in London, who developed the model, I will kind of go through each of the different scenarios and explain how they work. And at the end of that hopefully we'll have some

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sort of joint understanding of how the price formation process works, in the simplified model at least, and how you might use it internally.

So, here's just a quick agenda. First off, we're going to kick off with that model overview and purpose and then we're going to go through each of those scenarios. With each of them, we're going to have a pause for questions. It may be that for some of these, those questions are redundant. Please don't fear the tumbleweed moment. I think questions will necessarily - well, will be much more likely to emerge as we go to the later scenarios which are materially more complex.

What does the model do? The purpose of this model, at the high level, is an expository tool. So, essentially, it's there to help educate and inform stakeholders, very much as Charles said, in the philosophy that trying by doing is - learning by doing is the most effective way often of kind of understanding how things work. So, the model illustrates the mechanics of locational marginal pricing and it includes financial transmission rights and explains how the value of financial transmission rights and the payments - all the payments from financial transmission rights would be calculated.

It relies on a simplified and fixed network typology, and we'll just kind of go through it and talk a little bit about that. And it aims to show the impact of congestion on financial outcomes for generators and market prices flows and generation, in a market where LMPs is used to determine the prices that generators earn. So, what it's not supposed to be is any kind of representative model of the national electricity market. You should not reasonably think about using this model to make an investment decision. It's nowhere near complicated enough to enable you to decide where to invest.

The dispatch engine is simplified, and the results are themselves very simplified. And broadly speaking, what we wanted to do here was build a model which had very wide distribution. So very accessible low entry barriers to using the model and that's why we put it in Excel. But all that has meant is that the modelling logic had to be greatly simplified and so we kind of pushed the bounds of what reasonably sensible commercially available solvers are able to do in an Excel based platform that are kind of broadly accessible to all. We have used an open source solver in running the model ourselves. But the model is customisable to whatever solver you might have available and please do use the most appropriate solver for your business.

So, the solver that we've used may or may not meet your business needs and if it doesn't, then please do customise the VBA code in order to load a solver that you might - might be more appropriate. I mean the other thing

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that we don't do is we don't do anything - we have nothing about operating constraints beyond a kind of physical representation of the system, and we don't explain how FTRs are distributed or sold. So, there's no kind of explicit auction or anything like that in this model. This model is really about how dispatch works and what the implications of that dispatch would be for FTRs should they exist.

This slide here is just going to give you a quick overview of what's in the model. Because Mike's going to actually show you the model live and show you these sections but it's just kind of helpful sometimes to have a structure in your mind about what the different components of the model are. So, basically the main modelling sheet consists of a section where you can put in your input assumptions. And those input assumptions are load, their capacity for generation and then their capacity for transmission. And then after setting those inputs you can manually, or by setting them using one of our preloaded scenarios all by pressing the randomise inputs button. You can then press the solve button and magically LMPs and FTR outcomes appear in the section below, which is the modelling results and all the generation financial outcomes.

So, the modelling results just sets out the LMPs and the volume weighted average prices, and it also shows the kind of pattern of dispatch. So, it tells you where the generation is and how it's flowing around the network. And then the generated financial outcomes look at the payouts on FTRs if they were to exist, also calculates the settlement residue across a range of different load scenarios. So, you kind of see, well if the load were a little bit higher or a load were a little bit lower how would dispatch be affected and what would be the implication for the FTR payouts.

And so you can use that to hypothesise the impact of a generator with FTRs or without, in situations where the constraints bind on the network or do not, and that kind of provides a sense of the implications of market reform for generators at least in concept. So, this is what our network looks like. It's a four-node network and the reason for this really was it was the simplest possible network that we thought gave us the granularity we needed to show the different effects we wanted to show. So, it's, if you like, the Goldilocks size, just right. Just complicated enough to illustrate different outcomes that we're looking for and as simple as possible for internal exposition. And the reason we've got this particular shape is that we have one loop, and we have one branch. So, we can illustrate the impacts of constraints on linear bits of the network and we can also illustrate the impact of constraints on loops in the network.

So, for each node we can set generation and load, and then there are three types of generation in the model, each with their own marginal cost

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of generation. And so, the standard setting as we call them, solar, coal and gas but actually you could pick any technology name for sets of marginal costs you wanted. And in principle, if you really wanted to do some reprogramming and augmentation, because it's in Excel, competent Excel users could decide they were going to extend it some way, shape or form to include more technologies.

So, all generators in our model are assumed to bid marginal costs and that determines how they dispatch. So, the other way of thinking about this is to say the marginal costs column could be substituted with bid column in the input sheets. And that's essentially setting the way the prices get determined. So, we assume away transmission losses for simplicity. It ended up with lots of not very round numbers if we used transmission losses, which are less intuitive to follow but all the same principles broadly apply. The flows do obey the physical properties in the network in the sense that they follow Kirchhoff's laws and I'll explain in the next slide exactly what I mean by that. And then we've set VOLL as a parameter of $15,000 per megawatt hour.

So, what do I mean by saying power flows in the model obey Kirchhoff's law? Well, I mean really what I'm talking about is the loop on this network. So, imagine that I were to inject more power at node 1, to meet demand at node 2. And I'll interject one megawatt hour. Now for the purposes of the model, we have assumed that all of these transmission lines have equal properties. So, they all have the same reactance and resistance, they all have the same length. So, in that sense it's a very simplified network. Now in that - when you inject power at one, the power flows simultaneously towards node 2, on the direct line T12 but also on the indirect route T31 followed by T32 - 23. So, it goes both clockwise and anticlockwise around this loop.

And it does so, according to Kirchhoff's laws in proportion to the resistances that one would face on each of the two routes. So, given that there are two lines that go between node 1 and node 2 on the indirect route, and there's one line on the direct route, two thirds goes on the direct route and one third goes on the indirect route because the resistance is twice as large on the indirect roue, because we have twice as many lines, with exactly the same properties. So, for every one-megawatt hour we inject at node 1, then we have two thirds going to node 2 directly and one third going clockwise around the network.

So why is this important? It affects the way that prices will ultimately be determined and some of the scenarios, and particularly scenario 5 and 6, when we get to them later on, show the sort of outcomes that you get that result from this, which means that you can end up with LMPs which

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are different at every node - in every node in the loop, even if only one transmission line is constrained. And that was one of the key insights we wanted to make sure that people could use this model to explore so again, I think the next slide is just model prices.

So broadly speaking, we calculate two sets of prices. We calculate a locational marginal price and that's essentially the additional cost on serving load at each node for a one-megawatt increment demand. And then we have the volume weighted average price, which is the load weighted average of the LMPs in each individual node. And these prices are obviously the prices that are present in the access reform proposal, so that's the purpose of calculating them.

So here are six key scenarios that we're going to go through. The first is one they've dispatched. This is extremely simple, just looking at whether - how if we have load and generation at one node, how the price is set. So, very familiar with anybody thinking about a reginal or national market. Then we have two node dispatch in which we have two generators generating and we show the flows across the network. At this point we're still assuming constrain, unconstrained. And then scenario 3 then we run the entire network with some assumptions where there are no constraints, and just show the network flows.

So, on scenarios 1 to 3, we don't see variation in LMPs. The purpose is purely to show how dispatch works in an unconstrained system and power flows around the network. The scenario 4, we introduce congestion on the branch. And that creates a difference in LMPs and then in scenario 5 we have congestion on the loop, which creates different prices at each of the nodes on the loop. And then scenario 6, combines scenarios four and five and then we also use that in this presentation, just to kind of - that's the first time we'll be talking about the financial impact on generators.

So, we'll scroll down to the final panel on our model input sheet and look at the implications that that has for generators and describe how those outputs work. So, that is, I think, as much as we need to say about the structure of the model before Mike starts taking you through each of these scenarios in turn. And I think the next slide is probably a question slide. We shouldn't necessarily - absolutely agree we are open to questions, but we shouldn't necessarily prompt any, if we don't have any because I'm sure that there will be questions later. And some of the stuff later gets much heavier. So, we really want to hold our power if - keep our powder dry if we think that there's more value in answering questions later on in the presentation.

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MS MOLLARD: There is just one question here that might be worth quickly touching on, and maybe the answer is we'll get to it later. Victor Petrovski has asked is there a scenario with a line outage? So, does the financial settlement need to reflect system normal only. What happens with a planned or forced transmission outage and what defines a planned or forced outage on the real NEM system, not just the simplified model. So, there's quite a lot in there, maybe we'll get to it, but just interested in any initial reaction to that.

MR ANSTEY: Yes. So, the answer is no. You can cut the capacity on lines, but you can't actually cut the lines down to zero in the model. You can simulate the impact of a transmission outage by putting a very low - very, very low capacity on a line but you couldn't simulate a transmission outage. So firstly, the model is fully customisable, and you can put in any capacities you like. And one of the things you could do is put in a very low capacity on a line. You can't actually cut a line because it changes the physics of the network and the model doesn't recalculate based on the properties of what the physics of the network would be.

So, you basically need one of those Ds that's fallen over to be the typology of your network. But yes, as I say, you could simulate the impact of a transmission outage if you say - if you were to cut a line and you were essentially assuming that there were two parallel lines, one with twice as much capacity and one gets cut and then you've got lower capacity. So, you can do that. The scenarios that we have preloaded are a small subset, six of the infinite possibilities that are open to you. So, in the six scenarios that we have, we don't have that. We don't have the capacity being reduced on one of the lines but absolutely you could do that by doing that yourself in a custom scenario that you set up, subject to the point that I was making about you can't actually cut a line. You can't take it out completely.

MR WALKER: What I'd add to that then, just following up on the second part of the question (hello everyone, it's Tom here) is that yes you could work out what the numbers are with the lines as they are in one of the scenarios, then you could reduce one of the transmission lines, customise it, reduce the capacity of one of the transmission lines to replicate an outage. You could then observe the financial outcomes again. It is - and certainly in follow up to the question about what happens in the real world when that happens, is that the settlement residue, the congestion rent, the settlement residue will be reduced because the reduction in the flows in the line, and these FTRs payout a fixed quantity multiplied by the price differences.

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So in ordinary circumstances, the FTRs would not - the FTR payouts would not be reduced and it's sort of demonstrated mathematically that the FTR payouts will exceed, equal or exceed the settlement, sorry, the other way around, the settlement residues will exceed or equal the FTR payouts within a dispatch interval, provided the number of FTRs are consistent with the physical capacity of the system. So obviously if the physical capacity of the system is reduced, that means that the FTR payouts may in fact exceed the settlement residue that arises within the five minutes.

And to address that concern, the sort of negative implications of that, we've made a number of design decisions within the COGATI model, not directly relevant to NERA's work, which attempt to accommodate or alleviate concerns around that. Probably the most notable being that any shortfall in settlement residue to meet the FTR payouts could be made up from the revenue from the sale of the financial transmission rights in the first place. And we expect this will provide quite a substantial amount of additional revenue to back the FTRs.

MS MOLLARD: Great, thanks. We might move on then, George. I think it's over to Mike isn't it.

Presentation on the simplified model and Q&A

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MICHAEL: Just starting off kind of this is the main user interface for the model. The start of this an overview and it's the same overview George has just provided, so I'm not going to spend a huge amount of time on it but it's the same information outlining kind of the structure of the model, the three main panels, the inputs, the results and the financial outcomes. And then scrolling down we have the network typology. Again, exactly what George has just said on this.

So, I'm really going to start, in the first section, on model inputs. Now here we can customise all the inputs to the model. So, the first panel allows us to pick the generation fuel types. Now as default we have three fuel types that you can choose, and you can name these however you want. So, for instance we change wind to solar just by typing in here and you can also add the marginal cost for each fuel type. And as George says, in this model we assume that generators are bidding at marginal costs. So, this is in effect, their bid into the market.

Throughout the model we kind of abstract from time. So, we just talk about megawatts quite loosely. But each model solve relates to one dispatch interval so it's a single incidence of dispatch. In the second panel, you can then, having chosen your three generation fuel types, you can

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enter how much generation capacity you want to add for each fuel type at each node by just adding in the megawatts here, into these blue input boxes. And then in the next two kind of subpanels, you can also customise load at each node and also the transmission capacity for each line. So the transmission capacity of line that connects node 1 with node 2 is 100 megawatts here.

So those are the model inputs. So, you have a number of options in how you set that up. You can go through and type those in manually and really customise the set up of your model, or if you want to kind of generate a random scenario, you can just click this randomise the inputs button. And that will generate a random scenario, auto-populate these boxes and then you can go ahead and solve the model. If you kind of put in some custom inputs or randomise the inputs and you solve the model and you find you want to keep the results, or you want to save the inputs, you can revisit those results later to compare them.

We've built in a kind of scenario editor, so once you've solved the model with your inputs, you can enter a description for that scenario, so we can call it interesting or whatever, and you can click save the scenario here. And that will save the scenario to "my scenarios", which is a tab down the bottom. You can access it down the bottom of the Excel or you can click on the "go to my scenarios" button. And in here we've created space for you to store up to 50 custom scenarios. The inputs are actually saved along here, and you can keep saving these until you get to 50, and then it will just start overwriting the 50th scenario. If you want to clear scenarios, you can just click the "clear all saved scenarios" button up here.

If you then want to come back to that later you can choose your scenario to load using this drag down here. It will pull up the relevant description and then you can click "load scenario" and it will load the inputs. So, to demonstrate this, let me just resave this scenario, clear the inputs. You'll see I can drag and select scenario 1 and it's pulling up my really informative description and I can click "load scenario" and then it will load the inputs back in here for you to access. You've got to remember to solve the model, having loaded the scenarios. It's not just a one-off kind of load and solve.

So, as George says, we're going to work through kind of these preloaded scenarios to demonstrate the model. And we've loaded these in already. You can also see them at the bottom of the "my scenarios" tab. And these start very basically but we're going to kind of increase the complexity and just really use them to talk through how to view the results in the model. So, I'm going to start by loading scenario 1 which is a one node dispatch and if I click that, you can see its scenario loaded. I can check the inputs

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and you can see that we've only got generation capacity of one node, in this case node 4. We've only got load at one node, at this case node 4.

So, having loaded those inputs, I need to click Solve the Model. And once I click Solve the Model there'll be some whirring and then the model will solve. And then I can scroll down and get to the model results. So, the first panel of the model results are kind of an overview of system prices, which in this case is not that interesting because we only have one node. But you can see that we will report kind of load across nodes the locational marginal prices across the four nodes and then also the calculation of VWAP which is the load weighted average of those LMPs. We're going to focus in on node 4 and what's happening here. So here we have the pattern of dispatch and power flows panel. And this provides an overview of the whole system. So just to take this box for example, it's telling me at node 1 what load I'm meeting and if I'm not meeting load, what load I'm losing at node 1, and the total.

It's telling me generation, how much is generating of each fuel type, as kind of compared to their capacities, which I've input above. It's telling me net injection, so how much node 1, how much power node 1 is putting onto the network. So, if that number is positive it's putting the power onto the network. If it's negative it's taking power off the network. And also the LMP for node 1. Now obviously all of these are blank because we've only put node 4 in here for this example. So just to talk through the results for this example, you can see that we have 130 megawatts of load at node 4.

We've said that there are 100 megawatts of solar generation capacity and 100 megawatts of coal generation capacity in our example, so solar is cheaper in our case. We've inputted a marginal cost of zero. So solar fully generates here, and then the remaining that's not sufficient to meet load, so the remaining 30 megawatts of load are met by coal, which is kind of the next cheapest plant. The LMP is calculated as the cost to serve the next unit, an additional megawatt of load. So, in this case, the 131st megawatt. You can see that that would also be met by coal in this example, which has a marginal cost of $10 and therefore the LMP of the node is $10.

Now, in case this is quite confusing, you have to zoom out to see all these nodes, we've also built in a function below that you can zoom in at a particular node. So, you can just choose the node you want to examine and it's just going to bring the same information down but in a slightly more kind of laid out format, and clearer format. So, you can see the LMP, the generation, a summary of the marginal costs you've input, generation

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and capacity, a summary of kind of the load you're meeting at the node. And again, the net injection.

So that's a really simple one node example, so I don't know whether we have any questions on this, or whether it makes sense just to carry onto scenario 2.

MS MOLLARD: I can't see any questions coming through, so we might as well move on. It's all been very clear to me so far, thank you.

MICHAEL: Going to scroll back up to our scenario editor and we're going to load scenario 2. So again, scenario 2 is going to be relatively simple. We're just going to add another node. So, we're going to have a two-node model now between node 3 and node 4. So, you can see now we have generation and load at node 3 as well as node 4. So, we can click "solve the model" and move down to kind of the pattern of dispatch coming out of that model. Again, going to focus over here because there's nothing happening at node 1 and node 2. It's a similar pattern for node 4 which has 130 megawatts of load. So, it's going to meet it most cheaply by using the 100 megawatts of solar generation capacity it has. And then it's going to generate an additional 30 megawatts using coal generation to meet load.

At node 3, node 3 doesn't have any solar generation capacity, and it only has 50 megawatts of coal generation capacity, which is insufficient to meet the load at the node, which is 65. Instead of using gas generation, which is more expensive, it's going to use additional coal generation that's available at node 4. And it's going to take that 15 megawatts of coal generation at node 4, as a transfer along the line T3-4. And therefore, it's going to withdraw it from the network. So, you can see the net injection at node 3 is minus 15, whereas the net injection at node 4 is the 15. So that's the 15 megawatts of coal generation moving from four to three.

And then across both nodes, an additional unit of load is going to be best served, most cheaply met by coal generation at node 4. And if that load happens at node 4, it will just stay at node 4. And if it happens at node 3, that one megawatt will move from node 4 to node 3. And that means the LMP across both nodes is equal. And equal to $10, which is again the marginal cost of coal generation in our example. So again, very straightforward, just illustrating this is how the model will show you how power flows on a branch of the network, along with the direction of that flows. And just showing that these net injections are kind of positive when they're putting power on to the network and negative when they're taking power off the network.

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So, I'm going to carry onto scenario 3. So, loading up scenario 3, we're now just going to expand that to the whole network. So, we're going to bring the loop into play. So, we're going to have generation and load across the entire network. So, solving the model here, we're going back to look at kind of across the four nodes. So, I'm going to focus in on node 1 and node 2 because what we've done is, we've made node 1 - it has a relatively high amount of generation related to its load, whereas node 2 has relatively little generation capacity relative to its node.

So basically, we're going to use node 1 generation to meet load at node 2. In this case, at node 2, you can see it has 200 megawatts of coal generation which it can utilise, but then it still needs to meet another 200 megawatts of load. Instead of using its gas generation, it can instead use coal generation from node 1, which is going free because we only need to use the 100 megawatts of coal generation in addition to the 100 megawatts of solar generation, to meet load at node 1. So node 1 injects that 200 megawatts of coal generation into the system, has a net injection of 200 and because of power flows in the system, as George explained, we're going to have two thirds of that power move on the line from node 1 to node 2. And one third of the power move from node 1 to node 3 to node 2, around the long way here.

So that's the two thirds, one third split of these 200 megawatts around the loop. And then you can see on node 2 the net injection is negative 200. It's taking that 200 megawatts off the grid and using it to meet load. Now, if you cast your eye across all nodes, you'll see that an additional unit of load at each node, can actually be met by an additional unit of coal generation at node 1. And so again, the point here is that the LMPs are equal across all the nodes. There's no congestion in the system. And the LMPs are going to equal $10, which is again the marginal cost of coal.

So just briefly going up to the system prices panel, up the top here, you can see that we're meeting load at all nodes. You can see the LMP is $10 at all nodes. And therefore, the VWAP, the volume weighted average price is also $10. There's no variation. So again, the key thing we want to illustrate with this example is this pattern of power flows that's happening. There's two thirds, one third because of Kirchhoff's law. And the fact that in the absence of congestion anywhere on the network, the LMPs are going to be equal.

I'm going to move on to scenario 4 which gets a little bit more interesting. So, scenario 4 also utilises the entire network but we're going to introduce congestion. And the point of this scenario is just to show that congestion

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can lead to differences in LMPs across nodes. So again, we're going to kind of look across the network and we're going to see that node 2, as before, has relatively little generation compared to its load. And also node 3 has not enough solar generation to meet its load. So, both of these nodes need to source generation from elsewhere.

You can see that node 4 has 150 megawatts of free coal generation, because it only has a load of 100 and it has a capacity of 250 coal. So, it could cheaply meet both load at node 2 and node 3 given node 1 is using all of its generation to serve its own load. However, it can't get enough power to node 2 and node 3 because the line between node 3 and node 4 becomes congested. You can see that it's at full capacity here. And what that means is instead of node 4 being able to use this coal generation to meet load at node 2 and node 3, we actually have to turn to gas generation at node 1 and gas generation at node 2 to meet the extra load.

Now what does that mean for LMPs. It means that the LMP at node 4 is different to the LMP at node 1, 2 and 3. So one additional megawatt of load at node 4 can be met by an additional unit of coal generation at node 4. And so as before, the LMP at node 4 is $10. At nodes 1, 2 and 3 an additional unit of load at any of those nodes is met most cheaply by gas generation which is free at node 1. And therefore, the LMP at node 1, node 2 and node 3 is $20, the marginal cost in our example of gas generation. So scrolling quickly to "system prices" you can see now we're getting variation across the nodes, so you can see the $10 for node 4 as opposed to the $20 across nodes 1, 2 and 3 and therefore the VWAP is going to differ from the LMPs, as in the previous example. And in this case, it's 19.3.

MS MOLLARD: There is a question which we might just ask. I don't know if this better placed for you or for someone from the AEMC team, but someone's just commented that there's no line item for non-scheduled generation and that we should include a line item to think about non-scheduled generation. So that's stuff that's not scheduled, to evaluate how it will impact the VWAP price. And I guess one way that you potentially could do that is to use one of the load nodes. But I'm not sure if that could go negative. But if not, I guess that's useful feedback for us to think about. But I don't know if Michael or George, or Tom, any of you want to respond to that.

MR ANSTEY: I think my instinct was exactly the same as yours. The way you do that would be node off load and then you'd basically take the non-scheduled generation out of the volume of load. It's a good question about whether it can get a negative. I hadn't thought about that particular

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question. So, Mike, do we have a restriction on the load that it can't go negative in the model.

MIKE: Yes, we do in the model that comes through. That's not to say that the constraints won't work if it goes negative. I'm just trying to think that through now, but that's quite - - -

MR ANSTEY: So, in essence, at the moment, you can only model non-scheduled load by putting it as a reduction to load.

MIKE: I mean if you were up for it, you could change the - you could have this also as a constraint in the model and add it in if you wanted to change it that way as well.

MS MOLLARD: There's another question. Do we have any scenarios with batteries in the network?

MR ANSTEY: No. We don't have - we're not running multiple periods, so batteries are just generation in this context. It's a bit like - you could call one of these batteries and assume it had a lower cost in some previous period and therefore its opportunity cost is defined by whatever its opportunity cost is. So you know if we went up to the input sheet, we could rename one of them gas, we could rename it battery and give it an operating cost that we thought reflected whatever the operating cost of the battery would be in this half hour. Because it's not lots and lots of periods, it's sort of battery don't have particular additional meaning. Similarly, as Mike put it, if you were up for it, one could add additional rows to the generation. But I mean that depends on the Excel savviness and interest, as well as a desire to edit VBA code on the part of the particular individual. So, it's really a question of whether your geekery extends beyond the electricity sector and into fiddling around with VBA code as well.

MS MOLLARD: I think there's a challenge there for people. There was another question about in the example there is unmet load. Is that load shedding? So that would be where everyone's wanting to be - to demand electricity and their demand can't be met, so you actually have to shed some load off the system. Is that what's happening in this example, or is that just more of a terminology thing?

MICHAEL: So, there's no unmet load in this example. So, if load was unmet in the model, so I can show you that very quickly. So, let's just make load very high at node 2, and "solve the model". You can see at node 2 now, we're getting lost load and that's how load is shed in this example and we're charging that at a $15,000 LMP. So that's how lost load will come through or load shedding in this example across all nodes.

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MS MOLLARD: We might move on then.

MICHAEL: So, we're going to move on to, I think scenario 5 if I'm not mistaken. Scenario 5 we're going to introduce congestion to the loop. So, scenario 4 we just looked at was a difference in LMPs across the branch of the network between node 4 and node 3. So instead of that we're going to just congest a line in the loop. So here you can see we've congested the line that's between node 1 and node 2. And the way we've done this again, like previous examples is we've made it so that node 2 needs to source generation from elsewhere. It has more loads than generation. And node 1 in this example has a lot of excess generation capacity relative to its load.

For the purposes of this example we've kind of got rid of node 4 a little bit. So, node 4 just sits out here and meets its own load. And there are no flows between node 4 and the rest of the loop. So, we're just going to ignore node 4 for now. So, if we think about where we are in node 2, we need to source another kind of 180 megawatts of load after we've used our coal generation. And we can see in node 1 that they have - node 1 there is 180 megawatts free coal generation. So, this might be the cheapest way to source this generation. Now remember for every megawatt that node 1 injects into the system two thirds flows on the line from node 1 to node 2 and one third flows on the line from node 1, node 3 and node 2.

In this case, this line between node 1 and node 2 becomes congested before 180 megawatts of coal generation can be sent and withdrawn at node 2. Therefore, we need to look elsewhere for the generation at node 2, and you'll see that it has its own gas generation which it can use. However, even if it use its own gas generation and the imports or the imports that the generation from coal at node 1, that total generation is still insufficient to meet the load at node 2, and so it's got to source generation elsewhere. So, if we look at node 3, we see that node 3 also has some spare generation capacity in gas. Now when node 3 injects a megawatt into the system, two thirds flow from node 3 to node 2 directly and one third flows from node 3 round via node 1, to node 2.

So given node 1 is already injecting a lot of coal and this line is congested, what that means is that node 3 cannot inject any power because one third of that megawatt of power has to flow around the long way round, via node 1, and this line is congested. So, in order to meet the load at node 2, what we actually have to do is back off coal generation from node 1. And reducing coal generation at node 1, by one megawatt means that we're freeing up two thirds of a megawatt on this congested line. And freeing up two thirds of a megawatt on that congested line allows node 3 to inject

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two megawatts into the network. So, we've backed off one megawatt from node 1 and we've injected two megawatts at node 3.

And that means because we're injecting two megawatts, there is two thirds of a megawatt flows that long way round. So you see we're backing off coal at node 1 to reduce this congested line by two thirds of a megawatt at a time and every time we do that, it allows us to inject two units of power at node 3 to meet load at node 2. So, let's look very quickly at what that means for LMPs. So as before, I said kind of forget about node 4 in this example, but you can see the LMP at node 4 is the marginal cost for gas. So, the 201st megawatt of load at node 4 is met by an additional unit of gas generation at node 4. That means my LMP is $20.

At node 1, an additional unit of load, so the 201st megawatt can be met by the coal generation that's free at node 1, and that's because it doesn't have to inject it into the network. It can just consume at the node. So, the LMP is the marginal cost of coal in that example, which is $10. At node 3, an additional unit of load, so the 441st megawatt of load can be met by gas generation at node 3. And so, the LMP is the marginal cost of gas which is $20 at node 3. Now what happens to meet another unit of load at node 2? Well, to meet another unit of load we have to back off node 1. One unit of coal generation at node 1. And we have to inject two units of gas generation at node 3.

So, backing up frees up this line. Injecting that two megawatts replaces the unit you just backed off and then sends the other unit to meet the additional unit of load. And so, what that means is, that you're incurring two times the marginal cost of gas at node 3, so that's two times $20, so $40, minus the - and you save the marginal cost of coal which you backed off. And that marginal cost is $10. So, it's going to cost you $40 minus $10 and that gives you an LMP of $30. And this effect is called the springwasher effect. So, we have this pattern of rising LMPs around the loop and around the congested line.

And I think the key thing to take away is that this means that a congested line somewhere in the network, so if we kind of take a step back from the simplified model here, and imagine a more complex grid, you know a congested line somewhere in that mesh grid can cause variation in LMPs elsewhere in the grid because of the kind of physical characteristics of power flows and how generation must subsequently be managed. So just to show briefly what this does for the pattern of prices, in the system prices tab, you can see that at node 1, it's $10, we're meeting it by coal. Node 2 is that $30, that $40 minus 10. At node 3, we have the $20 and node 4 of both gas.

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We're taking a volume weighted average price across load and you can see that the VWAP in this example would be $21.48. I'm just going to pause there on that one.

MS MOLLARD: Just whilst everyone thinks and anyone wants to write in a question or a comment, I just flag that Jasper's also said that it might be interesting to be able to play around with the impact of charging bids for batteries, just building on that earlier question. So again, I think we'd be interested in any feedback from people about what they'd like to see in the future in terms of this model, because it will help get us a better insight as to what people would like to better understand about the reform. So, if there is anything like that, let us know, we can take that into account. Also, as always, the challenge is there in terms of developing the VBA yourself to have a crack at doing some of that.

I think Tom you wanted to make a point.

MR WALKER: Just another interesting finding or insight about the springwasher effect which Mike's just gone through. The LMP at node 2 is $30 which is above the highest bid price of any of the generators on the network that were dispatched. So, it's possible as a consequence of the springwasher effect, that effect that Mike was explaining about two of the gas minus one of the coal can mean you get prices, LMPs outside of the bid prices of the generators. Indeed, above or below.

MS MOLLARD: And there's been a comment made as well, which I think is relevant to this example, so if you had a battery at node 1, you could charge it and instead of backing off coal - it's come through, not sure George, you're thinking about that.

MR ANSTEY: Sorry, I was just thinking, yes that's true. But if the model only kind of does one shot, so there's one event, one dispatch interval, so you can't charge and then discharge in the same period. So, you'd have to - in this model you would have to do it by adjusting load. I mean I'd say it's a little bit clunky, you'd basically have to run it and then work out what your bid price would be and then run it again with a different load assumption to reflect a pattern of battery dispatch, and then see whether the battery makes some money and it would improve things.

But I agree, it's an offline calculation rather than a kind of automated function. But if Jasper's keen to circulate a version with revised VBA, that'd be great. Love to see it.

MS MOLLARD: I think keep going Michael.

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MICHAEL: So, the last scenario we have is scenario 6 and this basically combines scenario 4 and scenario 5. So, it has congestion on the loop, resulting in the springwasher effect, as well as congestion on the branch, resulting in a different LMP between node 3 and node 4. So I'm not going to spend time going through this because the intuition is exactly the same as for scenarios 4 and 5. You can just see that we're getting the springwasher effect across nodes 1, 2 and 3. So $10, $20, $30 but now we're getting a differential in LMPs between node 4 and node 3. So, at node 3 it's $20 and at node 4 it's $10 because this line is also congested.

What I am going to do with this example is use it to go through our generation financial outcomes panel, which is the bit you haven't seen as I scroll down. Now, this panel is obviously accessible for all the scenarios, we're just doing it on this one because there's the most variation in prices, so it's the most interesting example. What this allows you to do is to see some general overview statistics relevant to FTR payouts, relevant to kind of settlement residue. And then it allows you to kind of deep dive into a particular generator and you can set up - you can choose to be a generator somewhere on the network.

You can choose your capacity, you can choose if you own FTRs or a product - a swap in the forward market, and then it allows you to simulate the model across a number of dispatch intervals. So, a number of times, just changing load each time, so keeping everything else fixed and then see how your revenues change across those runs. So, we're going to show you that as we go through here. So, taking the first panel, our first panel is calculating settlement residue. So, we have kind of two tables here. The first table is a table for load and it's just showing how much load is paying for power. Load is paying for power in this model at VWAP and so you can see the revenue we're collecting across the four nodes, and in total.

In the second table, we're summarising how much we're paying to generators for power in this particular example. So, generation is getting paid at their LMP. So again, we're just calculating that up and then the settlement residue is the difference between what load pays for power and what generation is paid for power. And you can see that that's the difference between the total revenue here for load in the top table, and the total cost for generation in the bottom table. And that's what we're reporting here.

So just moving onto FTRs in the model. So, we've only used one-way FTRs in this model, which is an option. So, they're only paying out if the congestion is in the direction with which you hold the FTR. So, you can hold FTRs in the model from any node or LMP to VWAP and from VWAP to

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any node and LMP. So, in this case, if you own an FTR between node 1 and VWAP, that FTR only pays out when VWAP is higher than the LMP at node 1 in this model and zero otherwise. So, we don't have two-way FTRs in this model with negative payouts.

What we're doing in these two tables is summarising the payouts for FTRs. So, if you hold an FTR from each node to VWAP, this would be the payout. If you kind of just look at this single dispatch interval, this would also correspond to the fair value of the FTR. Now in reality that doesn't quite work because you're obviously holding an FTR over a number of periods. But in this context of this model, that's what we mean by fair value. So, then we get to the generator financial outcomes panel and this is the part where you get to kind of deep dive into a specific generator somewhere in the network.

So, we have to start with an overview, which is just pulling down information from the pattern of dispatch above, across the nodes. So, it's showing you how much is generated, out of what capacity at each node. It's showing you the LMPs across the nodes and it's showing you the VWAP. So, the first thing you do is you need to select which node you want your generator to be at. In this case, I'm going to choose node 3, but there's a little drop down here that you can choose whatever node you want. You also need to choose what fuel type your generator is. Again, from the above, I'm going to choose gas and node 3.

And then the last thing you need to do is enter in a capacity and this capacity can be the same as the maximum capacity for the generator at that node. So, in this case it would be 200, but it can also be less. And if it's less we basically pro rata the generation across kind of individual generators at the node. So, if you put in a capacity of 100 here, and gas was generating 30, then your generator would be generating 15. So, having put in that information, I've selected my generator and the site, we're getting some information about in this current run, I'm only being dispatched at 15 per cent of my capacity. I'm only generating 30 out of 200. I'm getting paid an LMP of $20 and my revenue equal my costs because my marginal costs is also $20.

So, the next panel lets you choose whether your generator contracts forward in the forward market. We have just flat swaps built in, but again you can add in quite easily actually the additional products that pay out in different ways just by editing the Excel. In this case I'm going to choose to own a swap. I get to input the strike price of the swap, which I'm going to choose it at $20. And I also get to choose the volume of power that I've contracted under the swap. So, in this case, I'm going to choose 80.

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You can see I'm getting a negative payout on swap here, because VWAP is greater than the strike price of the swap.

So finally, you get to choose what FTRs your generator owns. So, in this case, my generator, I'm going to choose to own an FTR from node 3, which is the node I'm at, to VWAP, with volume of 80. And you can see again, we've laid out the calculation for the payout of the FTR, for a one-way FTR here. The final panel, the final outcome here is how you simulate the model across multiple dispatches. So, we're going to do it across five and for each one I get to choose how load varies in that interval of dispatch. And that's applying an adjustment to load across all nodes in the network at the same time.

Again, that's something you can change if you want, quite easily. So, in this case, for run 1 we're going to run the same network layout but with five per cent less load across all nodes. And then we're going to click "simulate the model" now that's going to take some time because it's got to run across all instances. But when it's done, it's going to display out term summary statistics that we've just gone through kind of panel by panel but in a single table. And if you want you can view it in some charts, basically see how your profits and your LMPs and your generation varies across runs.

So, the key thing here is that we're comparing in this left chart, profit whilst holding the FTR you selected, which is the light blue line and profit without holding the FTR you selected, which is the dark blue line. And you can see that the profit in this table here, the fluctuations in your profit are reduced by holding this FTR because it's protecting you against the difference between your LMP and VWAP, which is the price you're kind of approximating with the strike price of your swap. You can also see in the right-hand chart how a generation for your generator varies with the LMP.

So, for instance, when LMP is $20, your generation is positive. When LMP is less than $20 because I'm a gas generator, I'm not generating, so my generation is zero. So that's just another way that you kind of customise and then examine for generators.

MS MOLLARD: Michael, someone's just asked can you show the screen again where FTR payout. I think that was just if you can move up.

MICHAEL: In here.

MS MOLLARD: Jenny, hopefully that was what you were wanting to see, that bit. I also notice that there were a few comments coming through about the springwasher effect and Greg Williams has posted a link to an awesome very New Zealand-ish video about the effects of springwashers

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and the power system, which is definitely worth the watch if you haven't seen it. It's very informational but also entertaining at the same time which is always best. Ron's also made a comment observing just some of the outcomes and how if you change some of these scenarios you would get different outcomes or even the same outcome as compared to today.

So, I think that's useful commentary, and this is really what we've set up this model to do. That people can play with it and compare what would happen under this world versus the current world. I guess the thing to mention, which is what George has highlighted before, is that this is a one-shot game. It doesn't repeat itself over time. So, you don't necessarily get some of those more dynamic effects that you'd get from playing repeated games over time, by using this model. So that's just one thing to bear in mind. George or Tom, I'm not sure if you want to add anything else to that.

MR ANSTEY: No, not really. I mean other than by saving scenarios, you can save up to 50 scenarios, so you could run it 50 times with 50 different sets of assumptions and that would give you some of the features of a dynamic game because you have lots of different types of periods in there. So, you can do that, but it's not directly intended to do that, you're absolutely right Victoria.

MS MOLLARD: Don't think there's anything else coming through.

MICHAEL: Okay. So, I'm going to hand back to George now just to talk a little bit more about model extensions.

MR ANSTEY: I mean we've actually covered quite a lot of this in the discussion and the Q&A, I think now. But I think what we really wanted to say was just there are plenty of other things that you could do with this model if you wanted to. So, you could include outages and actually we didn't put batteries on this list but absolutely you could customise the code to include batteries, have different regions, other network layouts and so on. The idea of this model is that everybody has something that is accessible and easy to use but for the people who are model focussed and interested in those kind of things, then of course because it's an Excel model it's customisable, it's not a black box. Anybody who has a working knowledge of VBA, and Excel can play around with it and edit the code and the structure of it.

So that's, I think all that really needs to be said on that. I mean it's 22 minutes past whatever hour it is, wherever we are. Victoria, there is time for a bit more Q&A if there are more questions. On the other hand, it might be that what people need to do is kind of go away and play with it.

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MS MOLLARD: Absolutely. I mean if everyone wants to pop in a question or a comment, happy to do that, otherwise perhaps the best thing to do is for people to go away, have a play and then send any questions or comments, or thoughts that they have back to the team. Hopefully, you all have our contact details by now, so happy to do that. I can't see anything else coming through. So maybe it is - I think you guys have done an excellent, excellent explanation of it. It is a lot to digest so perhaps that's the best thing to do, for people to go away and digest.

There is a question coming through which is a bit broader in terms of - probably one for Ben Davis, I think. It's more about the process for progression of the reform. So, noting that, if in future the NEM proceeds to put in place a dispatch nodal price engine, some major software platforms make an assumption on who owns the FRT value. Where will this be discussed, and it costs a lot to vary the software. So, I don't know Ben, if you just want to talk a little bit about some of the work we're doing, particularly with AEMO but then also participants to progress some of the software and costing design decisions.

MR DAVIS: I hope I'm interpreting the question correctly about the implementation costs and software costs implementing the reform. So, I guess in our 7 September paper we published some high-level estimates both based on a quick report we had done for us by Hard Software and also on some limited discussions with stakeholders. We noted in that, that we thought the cost side was a little low and that we'd be endeavouring to do future and further work on the implementation costs. And I think we will be progressing that. I think we're also - and we'll probably raise this in our technical working group that's coming up soon, we'll be very interested once we have consultants on board to get assistance from participants, to participate in interviews with our consultants and us, to gain further information on what those costs are for participants.

We'll also be working with AEMO on what the costs are for the system operator of implementation. So, I guess those are probably the key areas where we'll be considering further work on estimating those costs. I also think we've highlighted we're very keen to engage with industry on implementation timeframes and coordination with other reforms, in particular the other 2025 reforms that are ongoing to see whether synergies can be made, and costs can be reduced. So hopefully that's answering the question. But if you're angling at something else because I'm not entirely sure that's where you were going, please post another question.

MS MOLLARD: Thanks Ben. I think that's really an important point you made that we're going to need to continue to work with AEMO,

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participants as well, through the process to work out what exactly is the right functionality of any future reform and the software to go along with that. There are a few other questions coming through, so one from Jasper back to the NERA guys. Is there a similar model with an RRP? Just want to talk about - I had thought the regional price was included in that but perhaps you could just talk to that George.

MR WALKER: Perhaps I might. George was looking puzzled. I don't know whether you were going to get to the answer. I think by RRP Jasper means defining the regional price to equal the LMP at a particular mode. So would pick a node, node 1 and then say well the regional price for all load pays is the LMP at that node 1. I assume, George and Mike, that would be again something that would be relatively easily tinkered with through the code.

MR ANSTEY: Yes. I mean you wouldn't even need to adjust the VBA code. You could just put up a little table on the bottom saying RRP equals LMP at node and replace that with the references to VWAP. So, the whole thing could be edited in the way that any Excel file could. It isn't set up to automatically report RRPs. I suppose partly for that reason. RRPs are quite simple to calculate from a series of LMPs. So, in that sense we don't do that. There are some other questions here. We could just turn to those.

How do those prices go to supporting new investment in transmission? Can you model a transmission upgrade, and how is it marginally priced? I mean you can model a transmission upgrade by increasing the volume of transmission and capacity on any of the transmission lines. And Mike took us through the input sheets where you could do that. I'm not quite sure I understand the how is it marginally priced question. There's no automatic benefits calculation from a transmission upgrade. So, you have to do that again offline. You have to say what's the additional value in this hour of having upgraded transmission. nd the answer is the congestion rent on that line.

MR WALKER: You could work out the cost of fuel under one set of transmission infrastructure, change the transmission infrastructure, work out the change in the cost of fuel. That would be the value of that transmission infrastructure within that particular dispatch interval. As George has said it's a one-shot thing, so then working out trying to estimate that's over hundreds of thousands of dispatch intervals to work out whether a transmission infrastructure investment would be required. It's sort of beyond the scope of this model but conceptually you can do the most granular unit of that in this model.

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MS MOLLARD: Do you want to answer Ben's question about can the model extend to two regional VWAPs, George.

MR ANSTEY: It doesn't currently. But it wouldn't be difficult to go through and change the calculations so that instead of calculating one VWAP you calculate two. And the VWAP is calculated after the solver is run on the basis of the results, so it doesn't affect the dispatch. So, in that sense, it's an offline calculation at the end and that's pretty accessible. Any competent user of Excel who can press equals and multiply numbers together can calculate alternative VWAPs. Whereas, fiddling around with the interaction between the VBA and the solver is possibly a slightly higher bar.

MS MOLLARD: One again for probably Tom, so just one from Ron Logan. Under the proposed reform doesn't the calculation of the regional price change to the VWAP.

MR WALKER: Yes. To be clear, that's what we're proposing. We're proposing that the regional price would be calculated as the volume weighted average price of non-scheduled participants within a region. I assume that Jasper's question was related to the fact that he wanted to work out what would happen were we not to make that change and were we to retain the existing regional price calculation method, which is the LMP at a particular predefined node or the regional reference node.

MS MOLLARD: I think that's it for the questions.

MR WALKER: There's another one from Ben actually, Ben Skinner. I was particularly interested in how inter-regional inter-VWAP FTRs fit with intra VWAPs. I think then you'd be able to - again, this might be a little bit more complicated but you'd be able to - having defined the two VWAPs by defining two nodes in one region and two nodes in another region or three in one, you'd be able to define your two VWAPs and I think you'd be able to then define your FTRs as being a payout between those two VWAPs. And that would then, I think, get you to where you want to be, which is finding out what the payout would be between two VWAPs. Again, I'm just assuming George and Mike will tell me if all these things will break the model.

MR ANSTEY: No. I suppose I was thinking Tom just that if you want to divide two zones here, you'd probably have to - where you're going to put the division between the two zones, one is you could cut the loop, but in which case one of your zones. I mean there's going to be some interesting dynamics over the way that those two VWAPs work because you've got one loop that as soon as it has some congestion on it, ends up with quite

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different VWAPs. Or you could cut the branch, and the branch is one VWAP, but then in which case the branch is simply an LMP for the VWAP on that side.

So, it's kind of not automatically set up for this, so I think it would require a bit of fiddling around to produce something that you thought would give you the sorts of outcomes dynamic to see, if you wanted to model inter-regional VWAPs. Well, FTRs over inter-regional VWAPs.

MR WALKER: We do have, obviously in the NEM, our regions are - there are multiple interconnections between two regions. We do have looped regions. So, cutting across the loop would sort of represent that. But I agree with George, some caution might be taken as to interpreting the results on such a small model. You might get some quite peculiar, unrepresentative regional prices being spat out. With that word of warning, I think it's doable.

MS MOLLARD: Ron's just suggested something in the comments about whether you could alter the model to change the definition of node 4 to region B, with nodes 1 to 3 in region A and then use the LMP outcomes to calculate two different VWAPs as a proxy. Would that work do you think?

MR ANSTEY: Yes, absolutely. And that's, sorry, what I tried to suggest although possibly less articulately than Ron. And the - yes, absolutely. The VWAP at node 4 isn't very interesting in that case because it's just the LMP at node 4. Because those are all the nodes in that region. But you could just think of node 4 as being part of some large unconstrained region and then the LMPs are the VWAPs.

MR WALKER: I think Ron's next comment is actually a really interesting one, which is could you alter the model to change the definition - that wasn't Ron's. Somebody else made a comment which I think you've deleted Victoria, which I will try to find but it was essentially saying could you add nodes. I think somebody just asked that question. Could you add nodes? I think, again Mike and George, I'm probably way off my patch here but actually adding nodes is really hard. The Excel is kind of at its limits with the amount of nodes we've got. And the model is set to solve exactly the amount of nodes we've got. But maybe I'll let you elaborate and tell me I'm completely wrong on that.

MR ANSTEY: Yes. I mean I think the solver isn't overwhelmed but the constraints we programmed in reflect a matrix operation based on the physical constraints implied by a network of this structure. So, it would require some pretty heavy thinking and some testing if you were to change that. Because you'd need to reprogram the constraints to reflect

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the new network typology. You can't simply just add another loop and say it will all be fine.

MS MOLLARD: I can see Anton has his hand up. Can we take Anton off mute. I'm not sure if that's an error, or if he does have a question or comment but we can see - if you could take Anton off mute and we can hear from Anton.

MR KING: That was an accidental raised hand, apologies.

MS MOLLARD: Great, easy to fix then. Then Ron's just asked another scenario, so what about if there was congestion between nodes 3 and 2 with flows from node 2 to 1. That could give some interesting outcomes on node 1. Sounds like it would be a good thing for people to try and see what happens.

MR ANSTEY: Agreed. There are lots of interesting things you could do with this, lots of different scenarios. Do enjoy.

Explanation on how to install the model

MS MOLLARD: So,Tom Meares. Are you there somewhere? Do you just want to quickly remind people about how to ideally set up the model so that it works. Because we have had a few comments coming through that it isn't working for people. So there are some instructions and there's a user guide that goes along with it, but if you just want to quickly talk through it. That will be really helpful as well. Thanks Tom.

MR MEARES: Is it all right if I just share my screen quickly. Is that going to be okay? When you download the user guide for the model and if you choose to use OpenSolver that is suggested in the user guide, when you go to download it from this link you'll end up with a zip file that contains all of these different elements here. So, the first step that you're going to do is download that zip file and then save all of these elements into a single folder, all within the same folder. You're then going to want to go into that OpenSolver folder and then open this file here, which is OpenSolver.xlsm. You're going to double click on that.

Open it up - hopefully this is going to bring up just a blank empty Excel file and then when you've got this screen here, you're going to go back to the simplified model that you've downloaded from the link on the AEMC website and then when you've got this grey screen open, you're going to click open simplified model. That's going to open the simplified model itself into that grey window and then from there you just follow the steps in the user guide enabling the macros and making sure that OpenSolver is

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clicked on and all that kind of stuff. And from there, you should be able to run the model just as Mike has demonstrated today.

But again, if you've got any questions with that, please you'll see my email's been sent out somewhere, so please don't hesitate to send me an email and I can help you run through those steps to set it up. I think that's correct. George or Mike did you want to - please correct me, but I think that's what you've got to do.

MR WALKER: I might add something, which is the pitfall that we've all been - or the most common pitfall is not following the steps in that exact order. he order really matters. If you get the order wrong, it doesn't work and then you're ringing Tom up. And there may be other reasons why it doesn't work, in which case that's absolutely fine. It's obviously fine if you don't follow the steps as well, but it would save everybody a bit of hassle if you try to make sure you follow the exact order.

[video ends here]

MS MOLLARD: So, as we said earlier, that model is available on the registration page of our website and also on the project page as well, along with the user guide. There's no other questions coming through, so I'm just going to hand over to Michelle to wrap us up.

Closing remarks by Michelle Shepherd

MS SHEPHERD: Thanks to all of our speakers, especially George and Mike taking us through that model, I found it really interesting. I'm sure a lot of us are going to go away and have a little tinker and see if we can come up with some pretty wild outcomes. But we appreciate everyone coming along today, so that we can engage with you and get your feedback on the model and answer those questions that you've got. We certainly, as Charles said at the beginning, we can't do our job without your input. We will get much better outcomes if we work together with all of the participants, including all the market bodies and all of our stakeholders.

So, we do really want to hear from you about these reforms. And in particular about what you've seen today. So, we've had some feedback throughout the process about the complexity of the access reforms and we understand that that's a concern for many participants. And so, the idea of today and the idea of engaging NERA to develop the model that you've seen today, is about having us all understand better how things are going to work. It's not meant to replicate the NEM in all of its current complexity but it is meant to help you understand how it is that your own assets may operate and how outcomes may differ in the new environment

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that we're heading into, which is a really important part of the energy market transition.

We see these reforms as being fundamental to that. So, we hope that you found today's discussion valuable and that you will become more familiar with these reforms, and we really encourage you to continue to engage with the team. If you've got any questions - certainly, what I got out of today was a number of things. Firstly, in the absence of congestion, the reforms will provide no more complexity than we currently see in the market today. And where you do see congestion you will have a risk management tool that you currently don't have today to manage the risk of congestion, and that's in the form of financial transimission rights. So that is an additional right that participants can have to manage the risks that currently exist in the market and that we expect will grow and get worse over the coming years.

The third thing is that we understand that the reforms can be seen to be complex but we hope that through being able to work through these models and run those different scenarios, and we really appreciate all of the questions and particular ideas that came through today from everybody, that the more that you work through that, hopefully the less complex it will appear, because we can all start to understand how they'll work in practice. So, thank you to the NERA team. You've done a great job in getting to us a simple model that obviously can be enhanced as participants and anyone feels appropriate to deal with their own circumstances, or depending - I think someone said depending how geeky you are, as to how much you might expand what the team has put together.

But I think it's a great start, and so we want to acknowledge the work of the team and hopefully through that, that we can get to a much smoother transition to these reforms. But our process doesn't end here, in fact we're still very much in the early stages of our processes really. We have a directions paper out at the moment that we're looking forward to comments on. We'll be consulting widely on that over the coming months. In particular, as Victoria mentioned, we'll be engaging with participants about the cost of the reforms, including with AEMO of course, and that will be an important input into our ongoing processes.

So, we see these changes as being incredibly important. We see engagement with all of you as being incredibly important and so we just want to continue to talk with you. We encourage you to lodge a written submission by 19 October, and otherwise if you can't put in something in writing, then please talk to us. Contact the team through Victoria or Tom, or any of the other people that are here today. We encourage you also to

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sign up to our weekly newsletter, which you can do through our website, through our homepage, by the contact us button. And that will give you an update as to where all of our projects are at and what's coming up, including any future workshops or opportunities to engage on this might be.

And also signing up for alerts through our interactive calendar, which is on our website and is another great way of keeping in touch and being involved in all of our work program. We also want to continually improve with the way that we engage with all of our stakeholders. So, if you've got any feedback at all, good or bad things you'd like to see us do more of, or less of, please let us know, contact the team directly, send us an email. Let us know what you think what we could have done better today or what you really liked about today, so that we can continually improve with how we interact with all of you.

And otherwise, continue to reach out on any of the issues in any work program that we have. So once again, thank you for coming along today, we appreciate the time. As Victoria said, we're very conscious of how busy everybody is. So, thank you very much and we look forward to hearing from you further over the coming months.

MS MOLLARD: So that's it for us today. We'll give you back 15 minutes in your diary. See you all soon. Thank you.

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