RESEARCH NOTE

What happened on Black Monday?

An overview of the events on Monday 9 August 2021 and relevant aspects of New Zealand's electricity system

THE NEW ZEALAND INITIATIVE

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Introduction

Last week, on Monday 9 August, very cold weather over most of the country meant national electricity demand reached a record high. About 35,000 consumers (1.75% of consumers) experienced power outages between 7 – 9 pm.

The New Zealand electricity system is generally considered outstanding by world standards. The International Energy Agency (IEA), for example, stated in its recent review of New Zealand that we had a world leading example of a well-functioning electricity market and the market-driven rise in renewables was a world-class success story among IEA member countries.[1]

How, then, could we have a shortage of electricity last week? The reality is no electricity system is perfectly reliable. Almost all countries experience shortages at some stage. Although Monday's event was serious, it is important not to overreact.

The next section provides a brief overview of electricity sector arrangements relevant to Monday's blackout. The events of 9 August are then outlined, followed by brief comments about the investigations underway.

Background about electricity sector arrangements

Our electricity sector arrangements are well-developed, with operational responsibilities clearly specified for generators, the system operator and electricity distributors. We also have an independent and professional regulator, who is best placed to investigate what happened and decide the next steps, if any.

Information: electricity sector arrangements provide pretty good information about the risk of generation shortages

Considerable planning and reporting occurs for each winter period, defined as March – September. The system operator at Transpower provides reports to the Security & Reliability Council (SRC), which comprises an independent chair, senior executives from some generators and distributors and some consumer representatives. The SRC reports directly to the Electricity Authority Board and the Authority's Chief Executive typically attends all SRC meetings.

In regard to Monday's event, we are interested in the balance between peak demand and generation capacity. The system operator's forecasts for this are provided to the SRC in the generation balance report.[2]

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[1] "Energy Policies of IEA Countries," International Energy Agency, Ministry of Business, Innovation and Employment, 2017, 3. https://www.mbie.govt.nz/dmsdocument/181-energy-policies-iea-countries-nz-2017-review-executive-summary-pdf.

[2] The generation balance report for this winter is available at https://www.ea.govt.nz/assets/dms-assets/28/SRC09-Review-of-February-2021-New-Zealand-generation-balance-report.pdf. There are other reports covering other aspects of generation adequacy, such as the Annual Security of Supply Assessment that assesses generation adequacy for 10-years ahead, including covering dry year events. These are not directly relevant to the events of last Monday.

The generation balance report for this winter showed that under the Standard Base Case scenario, there were no days over winter where peak demand exceeded generation capacity. The standard base case is formulated with knowledge of generation that is scheduled to be offline for maintenance and generation needed to provide reserves to the system. The standard base case also assumes the largest asset in the system, which could be a generation or a transmission circuit, has, for some reason, tripped off. This is called the N-1 base case, where the "-1" refers to the loss of the largest asset. The generation balance report projected a 761 MegaWatt (MW) surplus of generation over peak demand for Monday 9 August 2021.

The full set of N-1 scenarios are:

1) Standard N-1 base case as described above.
2) Low gas supply, normal wind conditions and have N-1 situation.
3) Low gas, no wind and have N-1 situation.
4) Repeats of (1) – (3) but with peak demand for every day set at the level of last year's highest winter demand.

The generation balance report suggested sufficient generation would be available for all scenarios in (1) – (4) above. The scenarios in (4) are highly relevant to Monday's event as they reflected the coldest day in 2020.

The generation balance report also examines the above scenarios but with the second largest generator tripping off the system as well as the largest asset (called an N-1-G situation). This also showed surplus generation except for both of the low gas supply situations. In other words, almost everything had to "go wrong" for a deficit to occur. And even in that situation, the system operator can often access sufficient reserve generation to cover the shortfall.

To address the risk of a shortfall on the dates with low or negative generation balance forecasts, market participants are requested to (a) avoid scheduling additional outages which may remove or constrain generation and (b) adjust their demand and generation offers to minimise any risk of shortfall.

Note that generators are required by the Electricity Industry Participation Code (the Code) to provide their offers to the spot market 35.5 hours before real-time.[3] For example, generators provide their first offer for the 5:30-6 pm trading period on 9 August at 6 am on 8 August. They're allowed to update their offers every half-hour until one hour before real-time.[4] They are not allowed to alter their offers within one hour of real-time unless the system operator has instructed them to do so in a grid emergency or they have a bona fide physical reason to do so.[5]

The system operator forecasts demand at each node on the transmission grid and publish forecast prices for every node, which are updated regularly until 5 minutes before real-time. For several years there has been considerable concern among generators and major users about the accuracy of the system operator's demand forecasting. Coincidentally, Transpower released a request-for-proposal for a new forecasting system on the morning of 9 August!

People often ask why spot electricity prices are insufficient to ration demand to match available supply. The short answer is that behavioural responses to higher spot prices are too slow and uncertain to confidently keep the transmission grid stable.[6] Instead, a suite of automated responses

[3] Rule 13.6(1)(b) of the Code.
[4] Rule 13.17(1) of the Code.
[5] Rule 13.19(1) of the Code.
[6] The Appendix below provides a more detailed discussion of why spot prices cannot be used to always match demand to available supply.

are used, but when those are unlikely to be adequate, the system operator instructs manual demand reductions, as it did last Monday.

Incentives: generators have strong incentives to supply additional generation when spot prices are high

In broad terms, all generators receive the price offered by the marginal plant dispatched by the system operator, which means offering more plants doesn't suppress the prices a generator would receive for any of their plant that would be dispatched anyway. Also, no one in the electricity industry wants to cause blackouts as they know it can seriously harm their reputation and risks political intervention.

Hence, generators have strong incentives to avoid plant maintenance during winter periods because that is when they can expect to earn the highest prices. This is reflected in the published schedule of planned generation outages, which sat at 1200 MW for April 2021 versus 600 MW for 9 August 2021. In my experience, when spot prices are expected to be elevated, generators work very hard to get their plants out of maintenance to take advantage of the high prices.

Broadly, generators have strong commercial incentives to build the right mix of plant to serve demand. For example, if supply to meet peak demand is tight then generators with access to additional gas, eg Todd Energy, Contact Energy or Genesis Energy, have incentives to build gas-fired peaker plants to earn the high prices associated with winter peak demand periods. Peaker plants also cover other events where supply is temporarily constrained, for example when other generation units trip-off the system or a transmission constraint has become binding or hydro generation is low due to insufficient rain.

It is possible, however, that political considerations could outweigh those incentives. For example, the Government has signalled that it is not keen on gas-fired generation and has set a target of 100% renewable electricity by 2030. Gas sector shortages since late 2018 may also have stalled Todd's plans to build another 100MW peaker plant in the King Country.

Having said that, another option is to install a large battery unit to provide peak-smoothing services, which would be viewed by Government as consistent with a low-emission economy. I am aware some large generators and new entrants have been considering this option, however, at this stage, battery costs may still be too high.

Decision-rights: the system operator has the right to order distributors to cut power supplies

Generators are free to set whatever offer price they want; subject to the discipline they won't be dispatched if they price higher than the highest-priced plant dispatched by the system operator. The rules also require every generator to submit offer prices to the market on the assumption no generator has significant market power.[7]

If a grid emergency has been declared, then generators are required by the Code to do whatever they can to supply generation to minimise actual and potential impacts of any grid emergency.[8]

The system operator has substantial powers it can exercise in grid emergencies in regard to the operation of generation plant and it has the right to instruct electricity distributors to shed load (ie, cut supply to consumers connected to their networks). This is to protect the transmission grid from cascade failure, where many more consumers would lose power.

[7] Rule 13.5A(2)(a) of the Code. This is a new rule that came into effect on 1 July 2021, replacing a suite of other rules that included a requirement for generators to always offer their full capacity into the market (but of course they could choose whatever price they like).
[8] Schedule 8.3, Technical Code B, clause 3.

One of the consequences of the system operator ordering distributors to shed load is that it artificially suppresses spot market prices potentially undermining incentives for investment in peaker plants. The Electricity Authority dealt with this issue in 2011 by introducing a $10,000 per MegaWatt-hour (MWh) floor to prices when cuts to demand are ongoing (this is called scarcity pricing). The scarcity pricing regime also includes a $20,000 per MWh ceiling.

Numerous blackouts and conservation campaigns occurred in NZ prior to the creation of the wholesale electricity market in 1996, and in fact, the market was created because of rolling blackouts in the winter of 1992 due to hydro shortages. The market was widely credited with NZ avoiding blackouts (until now).

Ministerial interventions in 2003 undermined private investments in reserve generation, contributing significantly to serious supply shortages in 2008 but not blackouts. As a result, the Electricity Authority was created in 2010 with independent powers to monitor and investigate market events and amend the Code to promote competition, reliability and efficiency. As electricity is the most dynamic and capital-intensive industry in NZ, it is essential the Minister leaves the matter to the Authority who has the appropriate expertise and incentives to draw the right conclusions and decide any next steps.

What happened on Monday, 9 August 2021?

In short, 35,000 consumers (ie, households and firms) were without any grid-supplied electricity for up to two hours on the coldest night of the year to date. There are about two million consumers connected to the electricity system, so about 1.75% of consumers went without power.

On 9 August, very cold weather over most of the country caused national demand to reach a record high. The key milestones are:

- **6.40 am**: The system operator issued a Customer Advisory Notice (CAN) to market participants stating forecasts were signalling the possibility of a shortage of supply that evening, *should conditions worsen*. Many CAN notices are issued each year.
- **1 pm**: The system operator decided conditions had worsened and notified market participants further generation offers were required to avert the risk of demand management.

  By 1 pm it is too late to start the Huntly coal-fired units, as they take about 10 hours to warm up from a cold start. Electricity demand peaks over the 6 – 8 pm period, so the units would not be needed after 8 pm.
- **5:10 pm**: The system operator decided conditions had deteriorated further and a Grid Emergency Notice (GEN) was sent notifying market participants there were insufficient offers to cover both energy and reserve requirements and that reserves would be reduced to provide energy supply.

  My understanding is that the wind was very still in some parts of the country, and so wind energy was lower than the system operator anticipated. However, the storm conditions we experienced in Wellington was also hitting the central North Island, and this led to an unusual situation where weeds got into one of the Tongariro generation plants. So a 120 MW plant came off-line very quickly, amounting to about 1.7% of peak demand on 9 August.
- **6.48 pm**: The system operator requested all distributors to reduce demand by 1% and stated a Demand Allocation Notice (DAN) would follow.
- **7.09 pm**: The DAN was issued but it contained errors regarding the maximum demand limits requested of distributors. These errors resulted in several distributors, who had already

disconnected load in response to the 6.48 pm request, to further reduce demand. Oddly, the DAN requested the Tiwai smelter limit its demand to about 900 MW, which it can't do because it consumes a maximum of only 572 MW.

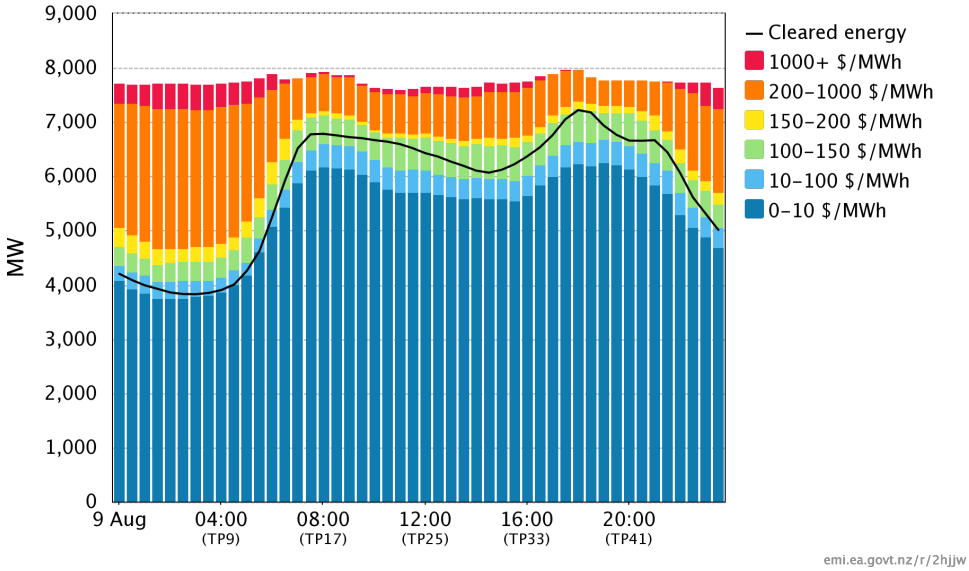
- **8.20 pm**: The 5 pm GEN was revised to allow distributors to return up to 5% of their current load levels.
- **9.01 pm**: The grid emergency was formally ended.

The initial request at 6:48 pm would have had little impact on consumers because power supply to hot water cylinders and street lighting is commonly the first steps distributors take to cut demand. It takes more than 4 hours for the water in most cylinders to become lukewarm.

However, the subsequent request at 7:09 pm led distributors to completely disconnect a portion of their consumers. This led to approximately 35,000 consumers being without electricity for up to two hours on 9 August.

With demand reductions being greater than required, generation was no longer dispatched as it was not required to meet demand (the system has to run with supply = demand otherwise it becomes unstable). This has led to the situation where consumers were without power while generation capacity was available to the system operator.

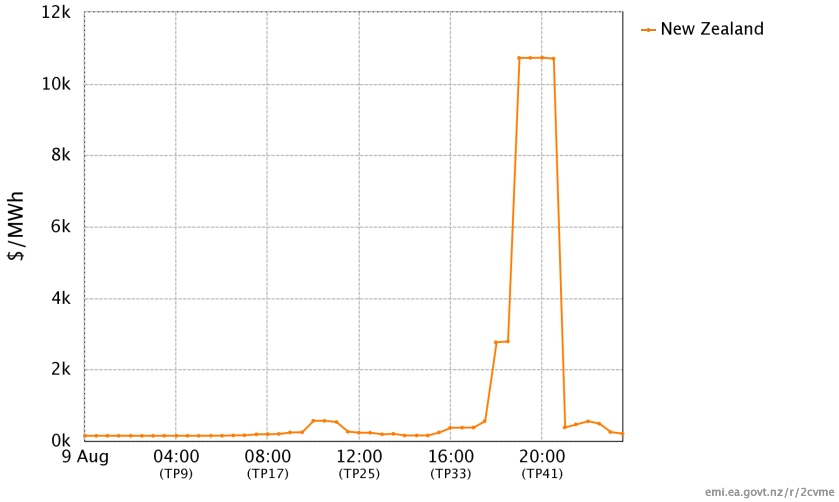
The following chart shows electricity demand (the black line) against generation offered into the market. I've coloured the bars so that you can also see where the spot market price may have landed if scarcity pricing hadn't kicked-in: spot prices would've been lower than $150 except for 6-6:30 pm when they would've been between $150 - $200/MWh.



Source: Electricity Authority

Peak demand occurred at 6-6:30 pm (7,220 MW). The chart doesn't explicitly show how much of the offered generation is used for reserves. Another chart I won't include here shows that 502 MW was used for reserves for the 6-6:30 pm trading period. Note, the drop in offered in generation around 6 pm, which is likely to be Tongariro tripping-off due to weeds.

It looks from the chart below that scarcity prices of $10,000/MWh applied from 7 – 8:30 pm.



Source: Electricity Authority

Even though it looks like the system operator's mistakes materially contributed to the consequences, it remains a concern the electricity system was so short of generation capacity. Investigations are clearly warranted.

What investigations are occurring?

The Electricity Authority is investigating the event in two phases.

- Phase one of the review will seek immediate assurance that any systemic and process issues that led to Monday's power cuts are urgently corrected. In particular, the review will be around the system operator's demand allocation tool and communications. This part of the review will be completed in two weeks.
- Phase two of the review will be wider than the system operator's role. The scope will be informed by the findings of phase one of the review.

The Authority has published the terms of reference for the review on its website.[9] This document states that the second phase of the review is likely to consider all roles (system operator, electricity distribution services, generators, retailers, direct connect consumers) and whether all generators that could run were running.

The Authority has also received allegations of an Undesirable Trading Situation (UTS). It will be interesting to see how the Authority addresses the issue that the very high prices have arisen from Code provisions (if that is indeed the case).

The Minister of Energy, Hon Megan Woods, has also instructed MBIE to undertake a review. They are likely to draw primarily from the EA's review.

Concluding comments

Blackouts occur in all electricity systems and Monday's blackout isn't necessarily an indication of a systemic problem. Repeated blackouts are a different matter. Ironically, the less frequent blackouts are, the more upset associated with them.

[9] See https://www.ea.govt.nz/assets/dms-assets/28/Terms-of-reference-Electricity-Authority-Review-of-9-August-2021-event-under-the-Electricity-Industry-Act-2010.pdf.

We should wait for the results of the EA's investigations before forming any conclusions. There are several operational and market design changes that could be made if there is a systemic problem.

Electricity systems are complex and vulnerable to tipping, where signals of government intervention can become self-fulfilling if sufficiently credible. It is important the Government allows the market regulator to identify and address the problems before even considering taking any action. It is also important the Opposition take an equally mature approach and resist the temptation to jump to conclusions and call for Ministerial heads to roll.

Appendix: Why we don't rely on spot prices to ration demand?

The laws of physics require the transmission system to be operated to keep electrical frequency within a narrow band around a target (in our case the target is 50 Hz). If a generator suddenly trips-off the system due to a mechanical fault or demand suddenly jumps by a large amount, then frequency falls within milliseconds. If the decline isn't arrested within milliseconds then it will cause other generation plants to trip-off the system, and frequency will go into free-fall and large parts of the grid or the entire grid can fail. This is called a cascade failure.

Spot pricing is too unreliable and too slow in such a fast-moving situation. Currently, volumes in the NZ market are settled on spot prices calculated for 30-minute trading periods. We have had indicative 5-minute prices for over a decade, but they're not reliable enough for settling against. The NZ market is moving to 5-minute settlement prices in November 2022, but even 5-minute pricing is far too slow to cater for real-time emergencies.

Unlike the trading of stocks, the spot electricity market is essentially a one-sided auction. The system operator forecasts demand at each node on the grid and conducts 250+ coordinated auctions with generators for their right to supply power to meet demand on the grid. The auctions are coordinated to ensure the right amounts of power are provided across the grid. Achieving this is a great deal more complicated than matching bids and offers on your local stock exchange.

Cascade failure has happened in other countries, including in several states in America and several countries in Europe. Cascade failure didn't occur on Monday. My understanding is that cascade failure has never happened in NZ.

Cascade failures are avoided through two mechanisms:

- Having some market participants operating in reserve mode, such that they can "instantly" inject electricity or cut their load. Not surprisingly, these are called instantaneous reserves and the system operator procures them via 30-minute auctions. The market rules set the procurement requirements based on a cost-benefit analysis.
- Having distributors install relays on their lines to consumers so that the relays trip automatically if frequency falls below specified levels. There are two sets of relays: one set to trip 16% of all load on a network and the other set to trip another 16%. The tripping of these relays is quite appropriately called automatic under-frequency load shedding (AUFLS). AUFLS events have occurred very infrequently.

The system operator used all of the instantaneous reserves available to it in the first bullet point.

About Capital Strategic Advisors (CSA)

Based in the capital city of New Zealand, CSA provides strategic policy advice to government and private sector clients. CSA has deep expertise in regulatory and tax policy, market design, pricing theory and practice, competition and infrastructure issues, and the implications of innovation and technology change for regulatory design, productivity, and economic growth.

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