Explanation by CFMMEU for Victorian Parliament Nuclear Enquiry

Wholesale electricity Market Bid Stack.

- AEMO uses historical data and forecast weather conditions to predict electricity demand for each 5 minute period for the next 24 hours.
- These AEMO predictions are extremely accurate.
- Generators are required to bid prices and volumes into the market in "good faith", 24 hours in advance.
- AEMO then constructs a supply bid stack selecting bids in the order of lowest priced electricity volumes first until the supply level meets demand.
- The last generator selected into the 'bid stack' (highest priced) then sets the system wholesale price for all generators that are dispatched by AEMO.
- Provided AEMO's predicted demand exactly matches the 'bid stack' supply then the electricity system will maintain its critical 50Hz design frequency.
- A low or high electrical system trip will occur if system frequency deviates by as little as +/- 2.5 Hz.

Ancillary Services Market Frequency Control

- If demand and supply are not exactly matched then the ancillary services market bidding system comes into play.
- In the ancillary services market bidding system generators bid small volumes of their electricity at various prices for 6 second raise or lower, 60 second raise or lower and 5 minute raise of lower.
- Again for ancillary services AEMO dispatches the cheapest bids first.
- This ancillary services market corrects for electricity frequency deviations, whenever supply and demand are mismatched over time.

Other Frequency Control Mechanisms

- Instantaneous mismatches in electricity demand versus supply are generally controlled by generator synchronous inertia slowing down the rate of frequency change so that generator governors can respond by either increasing or decreasing their load.
- Wind and solar provide no critical electricity system synchronous inertia or governor response.
- Synchronous inertia is absolutely critical to system stability because it slows the rate of frequency change enough so that automatic load shedding has time to restore system frequency or the ancillary services market has time to operate.
- Automatic load shedding sheds system load when there is insufficient supply of electricity in a pre-determined load order.
- Industrial customers are usually shed first, followed by domestic customers if further load shedding is required.
- Under the RERT AEMO can enter into contracts with industrial customers to pay them to load shed whenever there electricity system supply shortfalls, e.g. hot summer peak loads in particular.
- Portland aluminium is a very important load shedder for short durations because it consumes about 500MW.

Examples of 'Bid Stack' building by AEMO

Generators can bid selected volumes of their electricity into ten (10) different price bands. To simply our example see two (2) typical coal fired generator bids below:

Generator #1 542MW	**Band 1**	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 6**	**Band 7**	**Band 8**	**Band 9**	**Band 10**
$/MWh	-1000	12	25	34	38	45	50	120	2000	14000
MW	300	20	50	50	30	30	20	20	15	7

Generator #2 562MW	**Band 1**	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 6**	**Band 7**	**Band 8**	**Band 9**	**Band 10**
$/MWh	-1000	13	27	36	39	47	51	100	1500	14000
MW	300	20	50	50	30	30	20	40	15	7

Now, if AEMO forecasts a system demand of 998MW, then AEMO would construct the following 'bid stack' from the two generator bids shown above:

MW	Price
18	$51
20	$50
30	$47
30	$45
30	$39
30	$38
50	$36
50	$34
50	$27
50	$25
20	$13
20	$12
600	-$1000

The last dispatched bid would be $51 so Generator #1 will get paid: $51 for 500MW dispatched and Generator #2 will get paid $51 for 498MW dispatched, regardless of what they bid for in each lower price band. The wholesale spot market price in this case would be $51/MWh for customers buying on the spot market.

However, if the system demand forecast by AEMO was higher at 1053MW, then AEMO would construct the following 'bid stack' from the two generator bids shown above:

MW	Price
13	$120
40	$100
20	$51
20	$50
30	$47
30	$45
30	$39
30	$38
50	$36
50	$34
50	$27
50	$25
20	$13
20	$12
600	-$1000

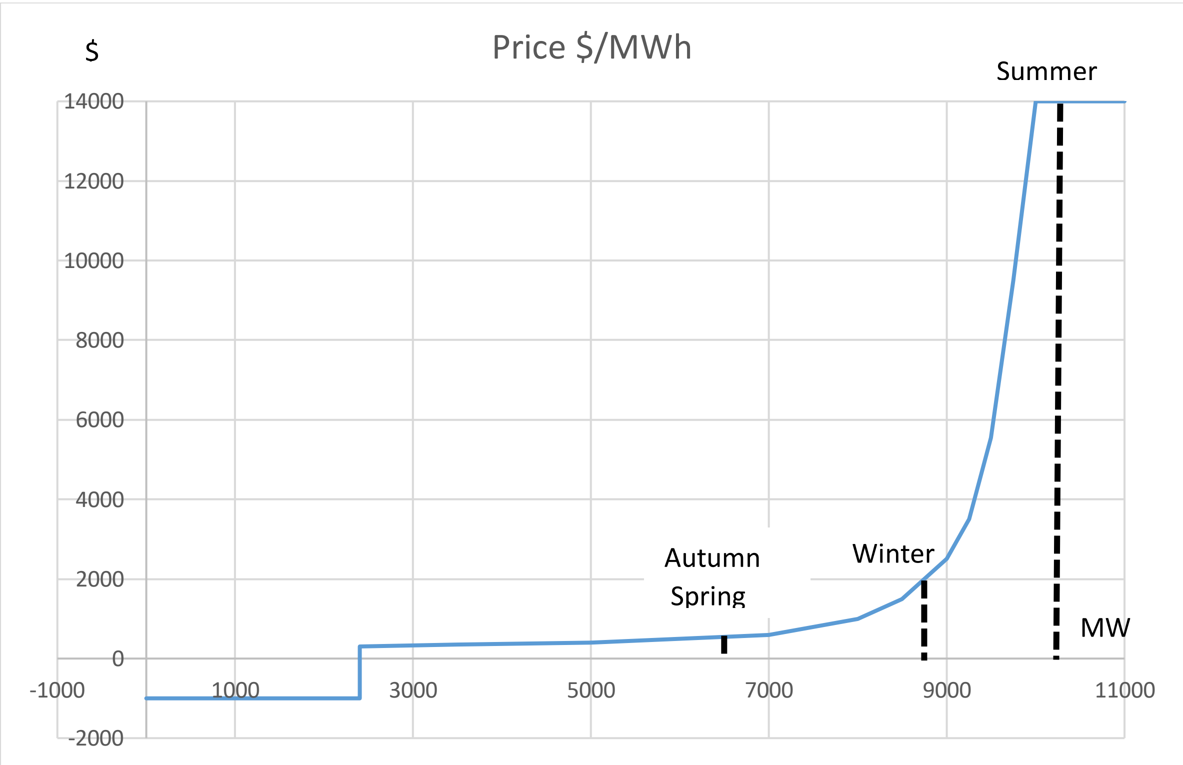
The last dispatched bid would be $120, so Generator #1 will get paid: $120 for 540MW dispatched and Generator #2 will get paid $120 for 513MW dispatched, regardless of what they bid for in each price band. The wholesale spot market price in this case would be $120/MWh for customers buying on the spot market.

Comments on Wholesale Spot Market Price

- Coal fired generators always bid a minimum of amount of their generation (where they need to use expensive support energy such as oil or gas) into negative price bands to avoid shutting down.

- To start-up a coal fired generator takes about 4-hours, if the steam turbine if hot, and up to almost 14-hours, if the steam turbine is cold. Support energy costs for start-up could be as high as $80,000, so shutdown and start-ups are avoided whenever possible.
- Running bids are normally based around the Short Run Marginal Costs (SRMC) of fuel.
- Wind & solar SRMC are pretty much zero and are dispatched on price in the bottom of the bid stack.
- Hydro marginal costs are low; however, they try to time water releases for peak power price periods to maximize their return on water resources and their limits on water releases across the year.
- Brown Coal SRMC are around $10/MWh.
- Black Coal SRMC are around $50/MWh for 2nd grade coal.
- Gas SRMC are around $80-$130/MWh.
- There is a maximum price cap in the bidding system of $14,000/MWh and a minimum price cap of -$1,000/MWH.

<u>Typical Demand Price Curve Behaviour</u>

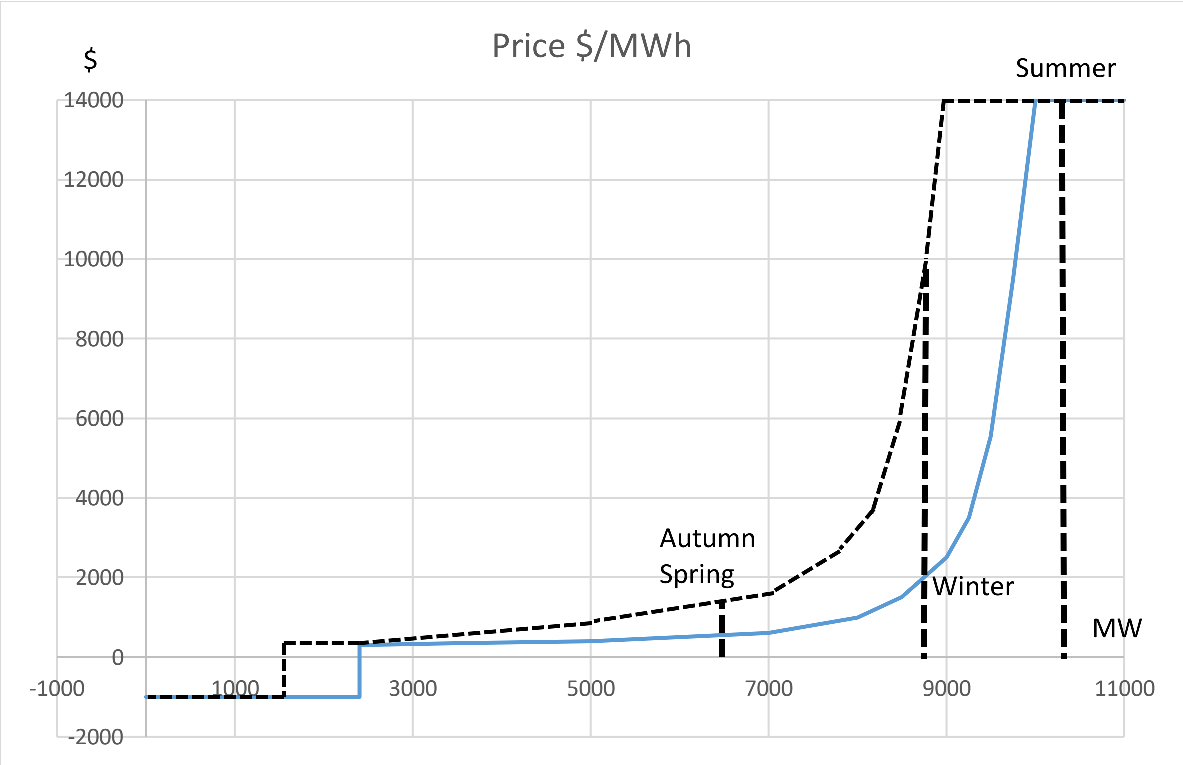


This illustration shows the seasonal peak demands, with demand dropping off further at night.

Wind and solar currently only makeup part of the generation mix but can't be dispatched to maintain supply and demand balance. As their bid price are generally low down in the bid stack they have minimal impact on price. The wholesale spot market price is set by the last dispatchable generator, which is normally not wind and solar.

Impact of Removing Dispatchable Generation

When a large dispatchable coal generator is retired (like Hazelwood) then the demand price curve shifts to the left due to the drop in supply and prices increase across the board. See below how the price demand curve shifts with the retirement of a large coal fired generator:



There are two main reasons that removing dispatchable generators leads to increased wholesale spot market price.

1. The last generator in the bid stack generally has a higher SRMC, which increases the overall wholesale market price. An example of this would be the increasing use of gas since the retirement of Hazelwood power station leading to increased wholesale prices.
2. With dispatchable generation becoming increasingly scarce, generators can price their power into higher price bands, leading to higher prices. This becomes increasingly necessary for generators as increased levels of subsidized wind and solar is added to the grid leading to supply excesses at times on very windy or sunny days, forcing dispatchable generators to off-load on price and to maintain system frequency. To make up for these periodic drops in generation revenue, the dispatchable generators (coal & gas) are then forced to price power higher when dispatchable power is in critical demand.

Removal of system demand will act in the opposite way to removal of supply on the wholesale system price. For example: the impact of Covid 19 on economic activity has dropped the system wholesale spot price from $100 - $130/MWH down to $40 - $60/MWh. Likewise, household Photovoltaic generation is not metered by AEMO but is seen by the system as a drop in the mid-day system demand.

Wholesale spot prices in the NEM can also separate between States, whenever transmission interconnectors are constrained by load or system stability limits because this can prevent the supply from being transferred to where the demand is. In this scenario high priced generation is dispatched in the local region that has separated.

Re: British Medical Journal Study

The British Medical Journal Study was an "observational" study that investigated the relationship between accumulated low-level exposure to ionising radiation for 308,297 nuclear workers in the UK, France and USA over a 27 year period. Researchers estimated excess deaths from ionising radiation exposure to be about 209 out of a total of 19,064 deaths.

As I am not a medical expert I will refer my answer to an article written in 'Medical Express' (attached) reviewing the BMJ study. Mark Little of the US National Cancer Institute, who is presumably an expert in his field, is reported as saying:

- This is an observational study in which bias cannot be ruled out. For example: they cannot rule out that exposure to occupational asbestos and smoking did not influence the results.
- He goes on to say "For the average worker, the lifetime risk of cancer death is likely to be increased by about 0.1% from a baseline risk of cancer of about 25%."
- However, he does agree "that the excess risks are unlikely to be zero."
- The review article concludes that "**the (BMJ) findings can also help strengthen the foundation for radiation protection standards.**"

I think this observational study must be treated with a degree of caution because it does not determine the causes of the cancers but merely infers it from observed data. For example, it would be logical to also submit that power station workers are exposed to accumulated high strength electromagnetic fields over their lifetimes (from non-iodising radiation) generated by high voltage transmission lines and transformers. Perhaps if this data were looked at it might infer the same finding but from a different inferred cause? Likewise, accumulated occupational exposure to other carcinogenic chemicals, such as oils used in the power industry might also infer a similar finding. It is always going to be problematic inferring the cause of cancers from observations, especially when comparing the general population to nuclear power workers. A better comparison would have been between coal fired power station workers and nuclear power workers.

In any case, the findings of the BMJ study should not be simply over looked because they may well add value to making the nuclear industry safer. It might well be that this study can be used to infer a more conservative exposure standard to be put in place for nuclear power workers. The current annual exposure limit to iodising radiation according to the NOH&S standards (attached) are 20 milliSieverts (mSv) per year, averaged over 5 years, with a single dose limit of 50 mSv.

It needs to be pointed out that prohibiting nuclear power <u>will not</u> remove worker exposure to iodizing radiation. According to the UK government, the average level of radiation exposure is 2.7 mSv in the UK and 6.2 mSv in the USA. The source of this radiation is that it naturally occurs in building materials and in Radon gas accumulation from the ground. A single chest CT scan dose is 6.6 mSv and an X-ray 0.014 mSv. A single CT scan for the whole spine dose is 10 mSv.

The BMJ might indicate that a reduced radiation exposure standard is needed but it does not conclusively prove that working in the nuclear industry is unsafe. For example, what would be the effect if the annual exposure limit were lowered to 15 mSv per annum?

Study provides more precise estimates of cancer risks associated with low level radiation

21 October 2015

More precise estimates of cancer risks associated with prolonged, low level exposure to ionising radiation among nuclear industry workers are published by *The BMJ* today.

The results suggest a linear increase in the relative rate of cancer with increasing radiation exposure and strengthen the scientific basis for current radiation protection standards.

Ionising radiation is an established cause of cancer, but information on radiation risk has come mainly from studies of people exposed to acute, high doses of ionising radiation, such as Japanese atomic bomb survivors. Research into associations between exposure to moderate or low dose radiation and risk of cancer began in the 1950s but estimates remain uncertain.

So an international team of researchers set out to investigate whether exposure to prolonged low doses of ionising radiation are associated with an increased risk of cancer.

The study involved 308,297 nuclear industry workers from France, the United Kingdom, and the United States. The workers, most of whom were men, were monitored for external radiation exposure, and were followed-up for an average of 27 years.

Risk estimates were then calculated for deaths from all cancers excluding leukemia. Factors such as age, duration of employment, and socioeconomic status were taken into account.

The estimated rate of mortality from all cancers excluding leukaemia increased with cumulative dose by 48% per gray (Gy). Similar associations were found within each country. Based on these estimates, the researchers suggest that about 209 of the 19,064 observed deaths due to cancer other than leukaemia were excess deaths associated with external radiation exposure.

The risk per unit dose was similar to estimates derived from studies of Japanese atomic bomb survivors, note the researchers, contrary to the belief that high dose rate exposures are more dangerous than low dose rate exposures.

This is an observational study in which bias cannot be ruled out, they say. For example, they cannot rule out the possibility that smoking and occupational asbestos exposure may have influenced the results.

"This study provides evidence of a linear increase in the excess relative rate of cancer mortality with increasing exposure to ionising radiation at the low dose rates typically encountered in the nuclear industries in France, the UK, and the USA," they write. The findings can also help strengthen the foundation for radiation protection standards, they conclude.

This study "adds to a growing body of evidence suggesting associations between exposure to moderate or low dose radiation and risk of cancer," writes Mark Little from the US National Cancer Institute, in an accompanying editorial.

But should we conclude, as this study does, that exposures at lower dose rates are just as risky as those at higher dose rates, he asks?

He suggests this conclusion may be unwarranted, pointing to several uncertainties, in particular the effect of the lower (but biologically more risky) energy of radiation received by these workers than in groups exposed at high dose rates such as the Japanese atomic bomb survivors. He also highlights a few weaknesses, including the lack of information on smoking and occupational exposure to asbestos, which "could conceivably confound the association between radiation dose and cancer risk."

He argues that the excess solid cancer risks associated with radiation in this cohort are modest. "For the average worker, the lifetime risk of cancer death is likely to be increased by about 0.1% from a baseline risk of cancer death of about 25%." However, he adds, "it is equally clear that the excess risks are unlikely to be zero."

More information: Risk of cancer from occupational exposure to ionising radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS) - http://www.bmj.com/cgi/doi/10.1136/bmj.h5359

Editorial: Ionising radiation in the workplace - http://www.bmj.com/cgi/doi/10.1136/bmj.h5405

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