SNOWY REGION BOUNDARY CHANGE PROPOSALS:

ANALYTICAL ASSESSMENT OF THE OPTIONS

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1. This paper sets out a methodology for assessing region boundary changes and applies that methodology to assess what conclusions can be drawn regarding the merits of the proposals before the Commission for changes in the Snowy region boundary.

2. This paper:

- Identifies the problems in the NEM which give rise to pricing, dispatch and hedging problems in the Snowy and other regions;
- Sets out a methodology for assessing the likely implications of a region boundary change;
- Briefly analyses a range of region boundary options for the Snowy region, highlighting those pros and cons which can be identified by proposed methodology.

3. The key conclusions of this paper are the following:

- There is no region-boundary-change-only option which will solve both the pricing and hedging problems in the NEM in the Snowy region. The current NEM Rules (which do not include some form of congestion management mechanism) do not allow for *both* efficient pricing/dispatch incentives *and* effective inter-regional hedging instruments no matter what region boundary option is chosen.
- Since no region boundary change alone can solve both the pricing and hedging problems in the NEM, the choice between region boundary options (including the status quo) is a choice between imperfect alternatives. The methodology set out here is not well suited to making judgments and trade-offs between imperfect alternatives. Some of the claims of the rule change proponents regarding the merits of their proposals relative to the status quo cannot be tested within this framework.
- The implementation of a congestion management mechanism of the kind considered in the congestion management review (such as a CSP/CSC mechanism or a constraint-based residues mechanism) could help to resolve *both* the pricing and hedging problems in the NEM *whatever* region boundary option is chosen (in the same way that the CSP/CSC Tumut derogation coupled with the Southern Generators' Rule Change goes some of the distance to solving the pricing and hedging problems in the Snowy region with the current region boundary arrangements).[1]

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[1] A congestion management mechanism would, in effect, establish the correct locational price signals for (at least) generators and would, at the same time establish a mechanism by which generators could hedge the price risks they face. There may remain a role for a region boundary change in correcting (or improving) the price signals faced by loads. It may be necessary to correctly price loads in the NEM not only to achieve the correct price signals for load dispatch and location decisions but to ensure that the hedging instruments available to generators are firm. This is a question for future research.

What is the "problem" in the Snowy Region?

4. The current NEM rules allow for the definition of "regions", "regional reference nodes" and notional "interconnectors" between regions, independent of the physical reality of the underlying transmission network.

4. There are two primary problems in the current NEM, both of which affect pricing, dispatch and hedging outcomes in the Snowy region:

(a) The first problem, the "mis-pricing" problem, arises because the NEM's regional pricing structure forces all generators in the same region to receive the same price (up to a fixed marginal loss factor) regardless of the presence of congestion in the region. When intra-regional congestion arises, some generators may be given output targets by NEMMCO which are higher than the amount they are willing to produce at that regional reference price. These generators (which are said to be "constrained on") respond by bidding "inflexible"[2], altering their ramp rates (to prevent the dispatch engine from increasing their output target) or by offering their output at a high price (such as VoLL). Such bidding behaviour threatens system reliability, reduces the efficiency of dispatch, and may give rise to negative settlement residues.

Similarly, when a generator is given an output target which is lower than the amount it wishes to produce at the regional reference price, such a generator (which is said to be "constrained off") responds by bidding inflexible, altering its ramp rate or offering its output at a very low price (such as $-1000). Again, such bidding behaviour threatens system reliability, reduces the efficiency of dispatch, and may give rise to negative settlement residues.

In addition, and possibly even more importantly, the lack of price signals for intra-regional congestion may distort generator and load location or expansion decisions and potentially harm incentives for investment. For example, an investment in low-cost generation which is remote from a major load centre and located on the wrong side of a transmission constraint is at risk of new, inefficient, investment locating nearby and aggravating that constraint. This problem is particularly acute when there is a region boundary between the remote generation and the load centre and the new entrant may locate in the same region as the load, but still on the wrong side of a transmission constraint.

(b) The second problem, the "hedging" problem, relates to the usefulness of the inter-regional settlement residues as a hedging device. When market participants trade electricity across separately-priced locations they take on risk. To offset that risk they need access to a hedging instrument which pays out an amount equal to the difference in the prices between the two locations.

In the NEM, the primary instrument available to market participants to hedge the risk of trading hedge contracts across regions are the inter-regional settlement residues that arise on the notional interconnectors between regions.

If these residues were "firm" (in the sense set out in the box below) market participants could buy a fixed quantity of the residues and thereby obtain a hedge for a fixed-quantity inter-regional contract. Unfortunately the inter-regional settlement residues are not firm either (i) in the presence of intra-regional constraints (which also cause the mis-pricing problem above) or (ii) in the presence of loops in the network. As a result, market participants cannot predict in advance the quantity of settlement residues they need to

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[2] The bidding rules in the NEM allow each generator to, under certain conditions, specify that it wishes to remain at a given target level of output. This is usually used for plant maintenance and/or safety reasons.

buy, and therefore market participants cannot effectively hedge their inter-regional transactions

5. The "pricing" and "hedging" problems have been a long-running source of concern in the NEM, and are reflected in a stream of rule change proposals such as the proposal for a CSP/CSC derogation at Tumut, the Snowy Hydro reorientation proposal, the Southern Generators' proposal, and the current Snowy region boundary change proposals. Such concerns also lie behind the MCE's request for the AEMC to review the mechanisms for managing congestion in the NEM.

6. Furthermore, in the NEM there is a secondary problem which interacts in various ways with the pricing and hedging problems noted above. This is the problem of generator market power. A generator has market power when it can, by varying its level of output, vary the price it receives for its output.[3] A number of generators in the NEM have, on occasion, a degree of market power. The presence of market power interacts with the pricing and hedging problems identified above in the following ways:

(a) A generator, in exercising its market power, may make a constraint bind more frequently or less frequently than the same constraint would bind in a competitive market. A generator in an importing region with market power has an incentive to try to impose constraints on flows into that region. A generator in an exporting region with market power has an incentive to try to relieve constraints on flows into neighbouring high-priced regions. Snowy Hydro, for example, claims that it uses its market power at Tumut to ensure that constraints north of Tumut do not bind. There is some evidence that the same practice has been carried out by generators in VIC at times of high prices in Snowy and NSW. The fact that a constraint is not observed to bind in practice is not evidence that that constraint is not having an impact on pricing and dispatch outcomes in the market.

(b) The mis-pricing noted above may mask a generator's market power. A generator which is constrained on or off will typically have little or no influence on the price it receives. Such a generator has little or no market power. On the other hand, improving the price signals on such a generator may allow that generator to exercise any market power it might have. It is possible that there might be an improvement in the efficiency of dispatch by alleviating the mis-pricing problem, but a decrease in the efficiency of dispatch brought about by the increased market power. In this circumstance, it would be desirable to address the market power problem directly at the same time as addressing the mis-pricing problem.

(c) It is widely accepted that a generator's incentive to exercise market power depends strongly on its financial contracting position. A generator's incentive to contract, on the other hand, depends on the prices and price risks it faces, any other risks, such as dispatch risks it faces, the hedging instruments available, and its expected opportunities to exercise market power. It is theoretically possible that a change in a region boundary will affect a generator's desired level and structure of hedge contracts by:

    (i) changing a price risk into a dispatch risk or vice versa (a remote intra-regional generator faces no price risk in contracting with the load located at the regional reference node but there remains a risk that the generator will not be able to produce as much as it wishes to produce at

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[3] In particular, the price the generator receives after taking into account any financial hedge contracts it has entered into.

the price it receives. In contrast a change in the region boundary would introduce price risk in contracting with the load centre, but would eliminate the risk that the generator is not able to produce as much as it wishes to produce at the price it receives);

(ii) improving or reducing the firmness of the inter-regional settlement residues (we might expect that, other things equal, the greater the effectiveness of the available hedging devices, the higher the level of contracting);

(iii) altering the incentives on a generator to exercise its market power (a generator which is fully contracted cannot exercise any market power that it might have. As noted above, the current mis-pricing may reduce a generator's market power and therefore increase its desired hedge level. A change in a region boundary might increase the ability to exercise market power and therefore might reduce the desired level of hedging).

At the present time, the drivers of a generator's hedging decision are not yet well understood. As a result, it is possible to say very little about the likely impact of region boundary changes on generator hedging decisions. These are important questions which may benefit from further research. At the present time, however, this area is not well understood and the conclusions we can draw are strictly limited.

7. In the light of these "problems" – the mis-pricing, hedging and market-power problems – this paper focuses on achieving the following objectives:

- Efficient short-term dispatch and pricing;
- Efficient inter-regional hedging (that is, access to a hedging instrument which allows participants to obtain a firm hedge for a fixed MW inter-regional transaction);
- Efficient longer-term generator and load location and expansion decisions.
- No increase in market power.

8. In this paper I will not focus on other criteria for choosing between options, specifically I will not focus on:

- Whether or not a region contains a minimum level of load. Many participants (including both Snowy Hydro and Macquarie Generation) have made reference to the recommendation by CRA that "no region shall have a maximum demand of less than 200 MW". Eraring Energy write: "this recommendation by CRA is in fact quite baseless with their report providing neither elaboration nor justification". [4]
- The "disruption", transition, or "set-up" costs of each option.
- The impact of a region boundary change on the static loss factors. The change of a region boundary will change the calculation of losses from a static to a dynamic basis and vice versa. Snowy Hydro claim that this impact is immaterial.

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[4] Eraring Energy, Submission to the AEMC, 22 March 2006, page 3.

- The impact of a region boundary on TNSP investment incentives. I have not analysed whether or not a TNSP might have stronger or weaker incentives to invest efficiently in the network following a region boundary change.

How should we go about analyzing each option?

9. These proposals are the first consideration the Commission has given to possible changes in the definition of region boundaries or interconnectors. There is not yet a developed or established methodology for assessing region boundary change proposals or changes in the definition of interconnectors.

10. This paper proposes one possible methodology. This methodology is based on the following observations:

(a) It is possible to obtain an indication of the extent of the pricing and hedging problems that will arise in a given configuration of regions and interconnectors by examination of the form of the (correctly oriented) constraint equations for that configuration; and

(b) It is possible to determine, in a relatively straightforward manner, the form of the correctly oriented constraint equations for any given configuration of regions and interconnectors.

11. These two observations, taken together, allow us to go some distance towards analyzing the implications of any given change in the definition of the region boundaries or the interconnectors. The limitations of this methodology are discussed below.

What can we learn by examining the constraint equations?

12. In the NEM, the market prices and the output targets of all scheduled generators and loads are determined by a central computer system known as the dispatch engine. The dispatch engine computes the combination of output targets (the "dispatch") which maximises short-term economic welfare, taking into account the physical limits of the national transmission network. The physical limits on the national transmission network are represented to the dispatch engine in the form of a number of mathematical equations (more strictly, mathematical inequalities) known as constraint equations.

13. Each constraint equation can be represented in the dispatch engine in the following form: (a) for each generator[5], a simple fixed number (known as the coefficient) times the output of that generator[6] plus (b) for each interconnector, a simple fixed number times the flow on that interconnector. The sum of these terms must be less than or equal to a number computed by the dispatch engine which is known as the constraint "right hand side". In mathematical notation, the constraint equation takes the form:

$$\alpha_1 Q_1 + \alpha_2 Q_2 + \ldots \alpha_N Q_N + \beta_{A \to B} F_{A \to B} + \beta_{B \to C} F_{B \to C} + \ldots \leq RHS$$

Where:

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[5] More strictly, for each "connection point". But since there is a virtual one-to-one correspondence between generators and connection points, the difference here is small.

[6] More strictly, the "net injection" at that connection point which is equal to any generator production less local load at that connection point.

α_i is the coefficient in the constraint equation on generator *i*, Q_i is the output of generator *i*, $\beta_{A \to B}$ is the coefficient in the constraint equation on the interconnector from region A to region B and $F_{A \to B}$ is the flow on the interconnector from A to B and so on; RHS is a number representing the physical limit in the network.

14. There are infinitely many ways of representing the same physical limit in the network in the form of a constraint equation. However, for any given configuration of region boundaries and interconnectors there is a unique way to represent the constraint equation so as to yield the correct pricing outcomes. When a constraint equation has been formulated in such a way as to yield the correct pricing outcomes it is said to be "correctly oriented".

15. A change in the configuration of regions or interconnectors has no impact on any physical limits in the underlying physical transmission network. All the existing physical limits in the transmission network must continue to be reflected in the constraint equations no matter what region boundary or interconnector definitions are chosen. However, the choice of region boundaries or interconnectors affects the way that a constraint representing a given physical limit should be formulated. Specifically, as noted above, the constraint equation must be correctly oriented for that configuration of regions and interconnectors.

16. A constraint equation is correctly formulated if both:

(a) the constraint equation is formulated in such a way that, in all regions, the coefficient on the net injection of power at the regional reference node for that region is zero;

(b) the sum of the coefficients on the interconnectors around any loop that exists between the notional interconnectors is zero. [7]

17. For a given configuration of regions and interconnectors, when a constraint equation has been correctly oriented for that configuration, we can, by observing the form of the constraint equation, make some observations about the mis-pricing and hedging problems that will arise when that constraint equation binds.

18. In particular, inspection of the form of the correctly-oriented constraint equation allows us to predict, when that constraint equation binds:

(a) which connection points which will be mis-priced;

(b) whether or not the inter-regional settlement residues will be "firm";

(c) whether or not there is a risk of negative settlement residues due to loop flow;

(d) whether the generator at a given connection point will be worse off (i.e., receive a lower price for their output) or better off (i.e., receive a higher price) following a region boundary change;

(e) whether a generator with market power has an incentive to use that market power to prevent a constraint from binding or to induce a constraint to bind.

19. Suppose that a correctly-oriented constraint equation has a non-zero coefficient relating to a particular generator's connection point. When that constraint equation is binding, that

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[7] The introduction of loop paths around notional interconnectors imposes a special requirement for constraints to be correctly oriented. See Biggar, "Orienting Constraints in a Network with Interconnector Loops", 24 November 2006.

generator will be mis-priced – that is, it will be "constrained on" or "constrained off". If the coefficient of that connection point in the constraint equation is positive[8], that generator will be constrained off, with the consequences for its bidding behaviour set out above. On the other hand, if the coefficient of that connection point in the constraint equation is negative, that generator will be constrained on, again with the consequences set out above. Therefore, we can determine which connection points will be mis-priced simply by observing which connection points have non-zero coefficients in the corresponding constraint equation.

20. One consequence of this observation is that, if we have information on the frequency with which certain constraints bind, we can use that information to determine the frequency and duration of mis-pricing at different connection points in the NEM. This observation was the basis for an earlier paper assessing the magnitude of the mis-pricing problem in the NEM.[9]

21. Furthermore, by observing the form of the constraint equation, we can say something about the "firmness" of the inter-regional settlement residues. It is important to be clear about precisely what is meant by "firmness". The concept of firmness that I will be using is set out in the box below:

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[8] Assuming that the constraint equation is formulated in the "less than" form.

[9] Biggar, "Congestion Management Issues: How Significant is the Mis-Pricing Impact of Intra-Regional Congestion in the NEM", 25 October 2006.

Concepts of "Firmness"

The majority of electricity traded in a market such as the NEM is covered by forward or "hedge" contracts. These forward or hedge contracts allow a market participant to shed some or all of the risk it faces from its exposure to the volatile electricity spot price, by effectively exchanging that volatile spot price for a fixed price. Efficient pricing of these hedge contracts requires that market participants are able to "arbitrage" differences in the prices of hedge contracts across different regions. However, market participants who trade across different regions face the risk of "price separation" between those regions – that is, the risk that will be forced to buy electricity at a high price in one region and sell it at a low price in another region, or vice versa.

In order to hedge the risks of trading between regions, market participants need access to a hedging instrument which has a payout equal to the price difference between those regions times a quantity which the participant can forecast in advance. When such a hedging instrument is available, the market participant can purchase the share of the instrument that it requires to perfectly hedge its inter-regional trade in fixed-quantity contracts.

I will say that a hedging instrument is "firm" if market participants can purchase a fixed share of the instrument in advance and thereby obtain a perfect hedge for the volume of fixed-quantity contracts the participant is trading between the two regions.

In the NEM, market participants have access to a hedging instrument known as the inter-regional settlement residues which arise on each of the notional interconnectors. Ignoring losses, these residues are equal to the price difference between two regions multiplied by the flow on the notional interconnector between those regions. These inter-regional settlement residues would be a firm hedging instrument if market participants could perfectly forecast the flow on the interconnector at the time the constraint is binding. However, in practice, this is not possible for two reasons:

(a) First, the "right hand side" of a constraint equation is not always a fixed number, for two reasons:

    (i) first, the underlying physical network is not perfectly reliable. Planned and unplanned outages occasionally reduce the physical limit on interconnector flow. This reduction in the physical capability of an interconnector is typically reflected in a change in the "right hand side" of the constraint equation.

    (ii) second, since a large component of demand for electricity cannot be directly controlled by the dispatch engine, terms relating to the demand for electricity are usually placed on the right hand side of the constraint equation. As demand changes, therefore, so will a constraint's right hand side.

    When the right hand side of the constraint equation is varying due to, say, the unreliability of the network or variability in demand, the settlement residues will not be as firm as is necessary to allow perfect arbitrage of hedging instruments. I will say that a constraint right-hand side is firm if it is equal to constant, fixed, number over time.

(b) Second, for the reason set out in the text, when there are other terms in the constraint equation, a constraint equation involving an interconnector may be binding at flow levels much below the physical limit of the flow on the interconnector.

In this paper I will say that a hedging instrument is firm if it is as firm as the underlying physical network allows – that is, if it is "as firm as the right hand side" of the constraint equation. This is not to imply that network unreliability is not important – it is very important – but it cannot be addressed using the tools of a region boundary change discussed in this paper.

22. What can we learn about the likely firmness of the settlement residues by examining the form of the constraint equation?

23. Suppose that a generator has a non-zero coefficient in a given constraint equation. Let's suppose that the same constraint equation also has a non-zero coefficient involving an interconnector. In this case, it follows automatically that the inter-regional settlement residues on that interconnector will not be firm even if the constraint right hand side is firm, for the following reason:

24. When a constraint equation includes both a term involving an interconnector and a term involving a generator, the total residues associated with that constraint (which are firm as long as the constraint right-hand-side is firm), are shared between the interconnector and the generator. The share taken by the generator depends on its level of output. Therefore, the share left to the inter-regional settlement residue fund also varies with the total output of the generator. Unless market participants are able to forecast the level of output of that generator when this constraint binds in the future, they cannot forecast what share of the inter-regional settlement residues they need to purchase in order to perfectly hedge the risks they face in inter-regional trading.

25. Even if a constraint equation has no terms relating to generator connection points, that constraint equation may still not yield "firm" settlement residues if that constraint equation includes terms involving two or more interconnectors.

26. In this case, the reason is that the total residues associated with the constraint (which, as noted above, are firm as long as the constraint right-hand-side is firm) will be shared between the two interconnectors. The share taken by each interconnector depends on its flow. As a result, unless market participants can forecast the precise flow on each interconnector when the constraint binds, they cannot forecast the share of the inter-regional settlement residues they need to purchase to obtain a firm hedge.

27. Both of these sources of lack of firmness – that is, when a constraint equation includes terms involving a generator and an interconnector, and when a constraint equation includes terms involving two or more interconnectors – can lead to negative settlement residues. (Negative settlement residues are just one, extreme, manifestation of the problem of lack of firmness).

28. In fact, if a constraint equation includes terms involving two or more interconnectors, negative settlement residues *must* arise, as long as the flow on at least one of those interconnectors has a sign opposite to the sign of its coefficient in the constraint equation. If there are two interconnector terms in a constraint equation with opposite signs on their coefficients, negative settlement residues will arise whenever the flow on those two interconnectors has the same sign. As we will see, this explains why negative settlement residues arise in the Snowy region when the Murray-Tumut constraint binds, and flows and uniformly northwards or southwards through the Snowy region.

29. Furthermore, it may be possible, through inspection of the constraint equations, to say something about how generators with market power will exercise that market power.

30. Suppose a constraint equation includes a term involving a notional interconnector. When that constraint binds, the price difference between the two regions joined by that interconnector has the same sign as the coefficient on the interconnector term in the constraint equation.[10] If the coefficient is positive, the "to region" will have a higher price than the "from region" and vice versa if the coefficient is negative.

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[10] Assuming that the constraint equation is formulated in the "less than" form.

31. If a generator located in, say, the "from region" of a given interconnector has market power, it will exercise that market power to relieve or "unbind" a constraint which has a positive coefficient on that interconnector. Similarly, that same generator will exercise its market power in order to bind a constraint which has a negative coefficient on that interconnector.

32. Finally, inspection of the constraint equations allows us get some idea whether the price paid to a generator at a specific connection point will go up or down following a region boundary change. The price paid for a generator's output at a particular connection point is equal to the price at the regional reference node for that connection point. Therefore, the change in the price paid at a connection point following a region boundary change is equal to the price difference between that connection point's original reference node and the reference node of that connection point following the region boundary change. It is straightforward to work out the difference in price between any two nodes by inspection of the constraint equation. Therefore, it is possible to work out whether or not a generator located at a connection point will be made better off or worse off (in the sense of receiving a higher or lower price) following any given region boundary change.

33. These principles can be made clearer by considering a specific example. The following constraint equation is one of a set of constraint equations used to represent a thermal network limitation between Murray and Tumut for flows in the northerly direction. Under the current region boundary and interconnector configuration, the correctly oriented version of this constraint (known as H>>H-64_B") takes the form:

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\begin{aligned}
&-0.81\times Q_{LT} + -0.792\times Q_{UT} + 0.165\times Q_{BLW} + 0.504\times Q_{HUM} + \\
&0.79\times F_{SNY\to NSW} + -0.164\times F_{VIC\to SNY} + 0.16\times F_{VIC\to SA(ML)} \le RHS
\end{aligned}
$$

Where

> Q_{LT} and Q_{UT} are the output of the Lower Tumut and Upper Tumut generators, respectively, Q_{BLW} and Q_{HUM} are the output of the Blowering and Hume (NSW) generators respectively, $F_{SNY\to NSW}$ and $F_{VIC\to SNY}$ are the flows on the Snowy-NSW and VIC-Snowy interconnectors, respectively, and $F_{VIC\to SA(ML)}$ is the flow on the Murraylink DC interconnector between VIC and SA.

34. Following the above principles, we can see that when this constraint equation binds (in the absence of any other congestion management mechanism such as the CSP/CSC derogation at Tumut and the Southern Generators' proposal):

(a) Upper and Lower Tumut are both mis-priced (constrained on) (since the coefficient on Q_{LT} and Q_{UT} is negative);

(b) Hume and Blowering are both mis-priced (constrained off) (since the coefficient on Q_{BLW} and Q_{HUM} are both positive);

(c) Neither VIC-Snowy nor Snowy-NSW residues will be firm (since the equation includes both generator terms and interconnector terms); and

(d) Negative settlement residues will arise when flow on VIC-Snowy and Snowy-NSW are in the same direction (that is, when flow is northwards through the Snowy region or southwards through the Snowy region) (since the VIC-Snowy and Snowy-NSW interconnector terms have the opposite sign).

(e) Snowy Hydro, located in the Snowy region, has an incentive[11] to exercise any market it has to prevent this constraint equation from binding (since the coefficients on the VIC-Snowy and Snowy-NSW terms are such that the Snowy region has a lower price than either of the other regions when this constraint binds).

(f) Finally, when this constraint binds, the price at the NSW RRN must be higher than the Snowy RRN (since the coefficient on the Snowy-NSW interconnector is positive) and the price at the Snowy RRN is less than the price at the VIC RRN (since the coefficient on the VIC-Snowy interconnector is negative). Therefore, we can deduce that a region boundary change which, say, places Tumut generation in the NSW region and Murray generation in the VIC region will increase the price paid to Murray and Tumut generation when this constraint binds.

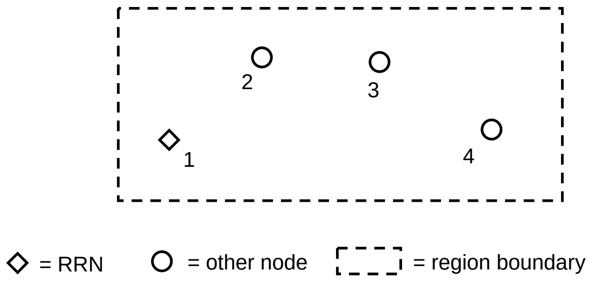
How do constraint equations change as a result of a region boundary change?

35. In the previous section we observed that it is possible to obtain some indication of the likely pricing and hedging outcomes that will arise in a given configuration of region boundaries and interconnectors by inspection of the correctly-oriented form of the constraint equations for that configuration.

36. In this section, we will see that, if we ignore losses, it is relatively straightforward to work out the appropriate correctly-oriented formulation of the constraint equations for any given configuration of regions and interconnectors.

37. I will only illustrate here the case of a division of a region and the merger of a region. The same principles illustrated here apply to more complicated region boundary changes.

38. Let's examine first the impact of a region division on the constraint equations. Suppose we have a network comprising a single region and four connection points labeled 1-4. Let's suppose that connection point number 1 is the regional reference node, and the other connections points are "remote intra-regional connection points", as illustrated:



39. In this network, the correctly oriented constraint equations will take the form:

$$\alpha_2 Q_2 + \alpha_3 Q_3 + \alpha_4 Q_4 \leq RHS$$ [12]

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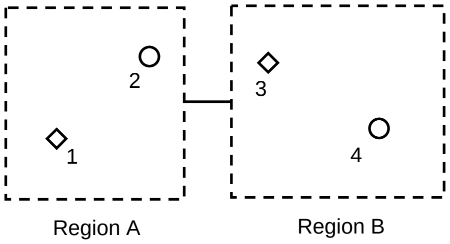
[11] At least, in the absence of any other congestion management mechanisms, such as the CSP/CSC derogation at Tumut.

[12] Note that the coefficient on connection point 1 (the RRN) is zero as required for the constraint equation to be correctly oriented.

40. Now suppose that this region is divided into two regions labeled A and B, with a new interconnector created (labeled "A-B"), with connection point 1 the regional reference node in the A region and connection point 3 the regional reference node in the B region, as illustrated:



41. It is straightforward to work out that the new correctly oriented constraint equations for this new network are as follows:

$$\alpha_2 Q_2 + (\alpha_4 - \alpha_3) Q_4 - \alpha_3 F_{A \to B} \leq RHS$$

42. Using the principles above, we can see that a region division of this kind:

(a) eliminates any mis-pricing that was present at the new regional reference node in the newly created region, no matter which constraint equation is binding (since there is no term involving connection point 3 in the above constraint equation);

(b) eliminates mis-pricing at remote intra-regional connection points in the newly created region in those constraint equations in which the remote intra-regional connection points happen to have the same coefficient as the new regional reference node in the former constraint equations (since in these cases the coefficient on connection point 4 is zero, since by assumption $\alpha_4 = \alpha_3$);

(c) creates new mis-pricing at remote intra-regional connection points in the newly created region in those constraint equations in which there was no mis-pricing of those connection points originally, but there was mis-pricing of the new regional reference node in the former constraint equations (since in these cases $\alpha_4 = 0$ and $\alpha_3 \neq 0$ so $\alpha_4 - \alpha_3 \neq 0$;

(d) has no effect on any mis-pricing that was present at remote intra-regional connection points in the original region (since the coefficient on connection point 2 remains unchanged); and

(e) will not yield firm residues on the new A-B interconnector as long as there is any mis-pricing of remote intra-regional connection points in either of the two regions (that is as long as either the coefficient on connection point 2 or connection point 4 is non-zero).

(f) results in a lower price for generation in the new region B if and only if the coefficient on connection point 3 is positive (and vice versa).

43. Now let's examine the impact of a merger of two regions on the constraint equations. Let's suppose that we have two regions joined by a single interconnector, as illustrated above. Now let's consider merging these two regions, retaining connection point 1 as the regional reference node in the new merged region (i.e., just the inverse of the region division above). Let's suppose the constraint equations in the original two-region network have the following generic form:

$$\alpha_2 Q_2 + \alpha_4 Q_4 + \beta_{A\to B} F_{A\to B} \leq RHS$$

44. It is straightforward to work out that the corresponding constraint equation for the merged region is:

$$\alpha_2 Q_2 - \beta_{A\to B} Q_3 + (\alpha_4 - \beta_{A\to B}) Q_4 \leq RHS$$

45. (It is easy to check by comparing this equation with the equation above that the process of dividing and then merging two regions restores the original constraint equations).

46. Again, using the principles above, we can see that a merger of two regions

(a) creates new mis-pricing at the former regional reference node of the eliminated region under any constraint equations which also previously included a term involving the interconnector (since the coefficient on connection point 3 is equal to the coefficient on the interconnector in the former constraint equation).

(b) creates new mis-pricing at the former remote intra-regional connection points in the eliminated region in those constraint equations in which there was previously no term involving those connection points but there was a term involving the interconnector (since if the coefficient on connection point 4 in this case is equal to the coefficient on the interconnector in the former constraint equation).

(c) eliminates mis-pricing at the former remote intra-regional connection points in the eliminated region in those constraint equations in which the coefficient on that connection point matched the coefficient on the interconnector (since in this case $\alpha_4 = \beta_{A\to B}$ by assumption)

(d) has no effect on any mis-pricing that was present at remote intra-regional connection points in the non-eliminated region (since the coefficient on connection point 2 is left unchanged).

(e) results in a higher price for region B generation if and only if the coefficient on the interconnector term is positive (and vice versa).

47. The region boundary change proposals currently before the Commission are somewhat more complicated than a simple region division or the merger of two regions, as illustrated above. Nevertheless, if we ignore losses, it is possible, via an extension of this sort of analysis to determine the appropriate form of the constraint equations following any given change in the configuration of regions or interconnectors.

What can we learn from this sort of analysis?

48. As already mentioned, the fact that we can determined the appropriate constraint equations for any given configuration of regions and interconnectors, coupled with the fact that we can learn some important information by inspection of the constraint equations, allows us to go some distance towards analyzing the implications of any given region boundary change.

49. Specifically, as already noted, this approach allows us to:

- Determine which connection points will be correctly priced and which will be mis-priced if a given physical network limit is binding following a change to the configuration of regions or interconnectors.

- Determine whether the mis-priced connection points are likely to be constrained on or constrained off;

- Give some idea of the impact of a change to regions or interconnectors on the firmness of settlement residues, and which generators can, by varying their output, have a direct impact on the settlement residues; and

- Give an indication of the scope for negative settlement residues to arise under a given configuration of regions and interconnectors.

- Give an indication as to how any market power will be exercised.

- Give an indication as to which generators will be better off and which worse off (for a given binding constraint) following a region boundary change.

50. However, this approach:

(a) does not allow us to make concrete predictions as to the precise impact on average prices or dispatch following any given region boundary change; and

(b) does not allow us to make concrete predictions as to the impact of a region boundary change on a generator's equilibrium contract level;

51. Let's look at these issues in turn. The actual pricing, dispatch and hedging outcomes that will arise in the market depend on precisely which constraints will bind and the frequency and duration of those constraints. There are a very large number of constraint equations, each of which has its own pricing, dispatch and hedging implications. The change in the incentives brought about by the new region boundary, will lead to new bidding and dispatch outcomes, and therefore to different flows on the transmission network. Therefore, following a change to the definition of region boundaries or interconnectors, new constraints may emerge as important, while other constraints which were significant under the old regions may become insignificant.

52. Therefore, while it is possible to make statements of the form "*if* constraint X binds, the pricing, dispatch and hedging implications will be as follows…", it is not possible to state with certainty (at least not without significant additional analytical or modelling analysis) that constraint X will bind with certainty.

53. Unfortunately under this approach it is also not possible to make concrete predictions as to the impact of a change in a region boundary on the equilibrium contract position of market participants. As already noted, a generator's incentive to contract depends on many factors, such as:

(a) the prices and price risks it faces;

(b) the reliability of its generating plant (and the availability of outage insurance);

(c) other risks, such as dispatch risk[13] it faces;

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[13] "dispatch risk" is the risk of not being dispatched for the quantity the generator would like to produce at the prevailing regional reference price – in other words, it is the risk that, as a result of being constrained on or constrained off, the output of the generator departs significantly from its desired level.

(d) the hedging instruments available to the generator, their effectiveness at hedging risks, and their price; and

(e) the generator's expected opportunities to exercise market power.

54. For example, consider the case of a generator which is mis-priced under the status quo, but which is correctly priced following a region boundary change (or vice-versa). Can we determine the impact of that change on the equilibrium hedge position of that generator?

55. Under the status quo, this generator faces no price risk in contracting with the load located at the regional reference node, but still faces some dispatch risk. That dispatch risk will be reflected in the desired contract level of the generator – perhaps that generator will build in some "buffer" or "margin" to account for the risk that it will not be dispatched to the level it desires.

56. On the other hand, following a correction of the mis-pricing, that generator will now face some price risk. The desired hedge position of the generator will now depend on the magnitude of that risk, the effectiveness of available hedging instruments and possibly other factors such as the extent of market power. The magnitude of that price risk depends on the frequency with which the relevant constraint binds and the price difference that arises when it binds. The effectiveness of the hedging instruments depends in part on the "firmness" of the settlement residues, which depends, in turn, on the ability of the generator to forecast the output of those generators whose output will affect the magnitude of the settlement residues, or to forecast the flows on those interconnector whose flows will affect the magnitude of the settlement residues. Furthermore, as already noted, a change in a region boundary may affect the ability of a generator to exercise market power and may therefore affect its desired overall contract level.

57. Assessing the impact of any change in the market rules on generator equilibrium hedging portfolios is not easy. At the present time, relatively little is known about the key drivers of generator hedge decisions. The approach to assessing region boundary change set out in this paper is not suited to answer questions about the impact of the region boundary change on generator equilibrium hedging portfolios.

What are the options that will be considered in this paper?

58. This paper will consider the following possible changes to the definition of region boundaries and/or interconnectors in and around the Snowy region:

(A) The status quo region boundaries, with no additional congestion management mechanisms (i.e., the situation in the market before the implementation of the CSP/CSC derogation at Tumut and the Southern Generators' proposal and without "clamping");

(B) The status quo region boundaries, with no additional congestion management mechanisms, but with Dederang included in the Snowy region and the regional reference node for that region (this option is included as a point of comparison with option G below).

(C) The status quo region boundaries with both the current congestion management mechanisms in place – the CSP/CSC derogation at Tumut and the Southern Generators' proposal (and without "clamping"). This option differs from the others in that it is the only option in which the use of other "external" congestion management mechanisms is considered.

(D) The Snowy proposal to eliminate the Snowy region and put Murray generation in the VIC region and Tumut generation in the NSW region. The VIC-Snowy and Snowy-NSW interconnectors are eliminated and replaced by a single VIC-NSW interconnector.

(E) The Macquarie Generation proposal to eliminate the Snowy region and to create two new regions – in Northern VIC and Southern NSW. The VIC-Snowy and Snowy-NSW interconnectors are eliminated and replaced by three new interconnectors (VIC-Northern VIC, Northern VIC-Southern NSW, and Southern NSW-NSW).

(F) The Eraring submission option to divide the Snowy region in two, between Murray and Tumut. The VIC-Snowy and Snowy-NSW interconnectors are eliminated and replaced by three (VIC-Murray, Murray-Tumut, and Tumut- NSW) interconnectors.

(G) The Split Region option in which the Snowy region is divided in two, with Dederang included in the Murray region, and the regional reference node for the Murray region.

(H) A hypothetical option in which there is a separate region around each generation node and interconnectors reflecting all the physical links between generation nodes. The VIC-Snowy and Snowy-NSW interconnectors are eliminated and replaced by six new interconnectors. This option is included only as a benchmark.

59. As noted earlier, it is possible to determine the transformation to the existing constraint equations necessary to reflect each of the options above in the constraint equations. Should we proceed by applying this transformation directly to the constraint equations in use in the NEM, or should we instead consider the constraint equations appropriate for a simple stylized representation of the NEM?

60. There would be some merit in applying these transformations directly to the constraint equations in the existing constraint library in the NEM dispatch engine. This would allow us to make concrete predictions as to the likely impact of a given region/interconnector configuration in the NEM when any given constraint is binding.

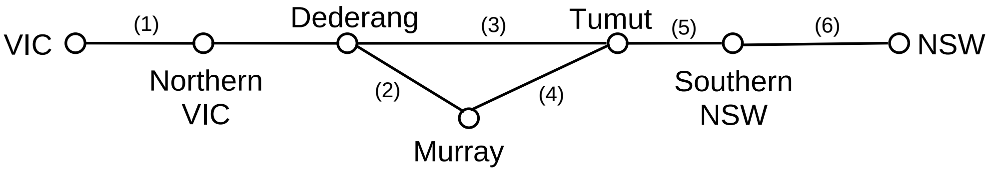
61. However, there are a large number of constraint equations in the existing constraint library. It is not possible to be certain which of these constraints will bind following a change in the configuration of regions or interconnectors. There are too many constraint equations to simply list all of the equations in their revised form. Nor is it clear that selecting a few constraint equations to illustrate how they would change under the new configuration is useful, as the selected constraint equations may not be among those constraints which are the most binding in the new configuration.

62. It may be possible to present some form of summary information about the revised constraint equations, such as a simple count of the number of constraint equations which mis-price a given connection point or which would give rise to negative settlement residues. However this approach also has its difficulties. The process of transforming the existing constraint equations only works for those constraints which have been written in the "fully co-optimised" or "option 4" form. Although a large number of constraint equations are already in this form, it is not clear that all relevant constraints are in this form and it is not clear that it is possible to identify those constraints which are not yet in the revised form.

63. For these reasons, rather than attempt to work with the constraint equations in the existing library of the dispatch engine, this paper illustrates the impact of a change in the configuration of regions/interconnectors using a simplified network model of the NEM with a limited number of constraint equations.

64. The simplified network model is set out below. This network is highly stylized. Although it reflects the network loop in the Snowy region, the VIC and NSW regions are represented in a

simple linear or radial manner. The location of the six physical network limits which are modelled are indicated below.



(n) = location of modelled network limits

65. This simple model abstracts from certain key features of the NEM. For example, the transmission network in NSW features a number of significant loops, including a large loop that includes the "western ring" generators. It is important to bear in mind that the network above represents a significant simplification of reality, and key results should be tested using the actual constraint equations which are in use in the NEM.

66. The following table shows a rough indication of the correspondence between the simple constraints in the network above and the constraint equations which arise given the current configuration of region boundaries and interconnectors in the current NEM.

Stylized network constraint	Corresponding constraint equations in the real NEM
VIC-Northern VIC	H>>V_NIL_3, H>>V_NIL_4x, H>>V_SMDDx, V::H_x, V>>H_NIL1A_R, V>>V_DDTX_x, V>>V_LTMSx, V>>V_X_DDTX
Dederang-Murray	H>>V_DBUSS_x, H>>V_NIL1x
Dederang-Tumut	H>>H_X65_66_X5_x, H>>N_LTMSx, H>>N_MSUT_1
Murray-Tumut	H>>H-NILx, H>>H-64x, H>>H-DDWOx, H>>H-JNWGx, H>>H-LOTFx, H>>H-LTMSx, H>>H_JNWG+X5_x, H>>H-051x, H>>H-07x
Tumut-Southern NSW	H>>N-03x, H>>N-CNLTx, N>>N-CNYS+UTYSx, H>>N-CNYSx
Southern NSW-NSW	N>>N-NIL_1x, N>>N-NIL_28, N>>N-22x, N>>N-26x, N>>N-81x, N>>N-AVDTx, N>>N-AVKCx, N>>N-AVMNx, and many others…

x= other suffix, e.g. ,A,B,C… or 1,2,3… and so on.

What are the pros and cons of each option?

67. Let's turn now to assess what we can say about the strengths and weaknesses of each of the options set out above.

Option (A): Status quo, no congestion management

68. Option (A) features the status quo region boundaries, with no congestion management mechanism (such as the CSP/CSC derogation at Tumut or the Southern Generators' proposal to offset negative settlement residues on the VIC-Snowy interconnector with positive residues on the Snowy-NSW interconnector).

69. This configuration features three regions (labeled VIC, Snowy, and NSW), with regional reference nodes at VIC, Murray and NSW. There are two interconnectors, labeled VIC-Snowy and Snowy-NSW.

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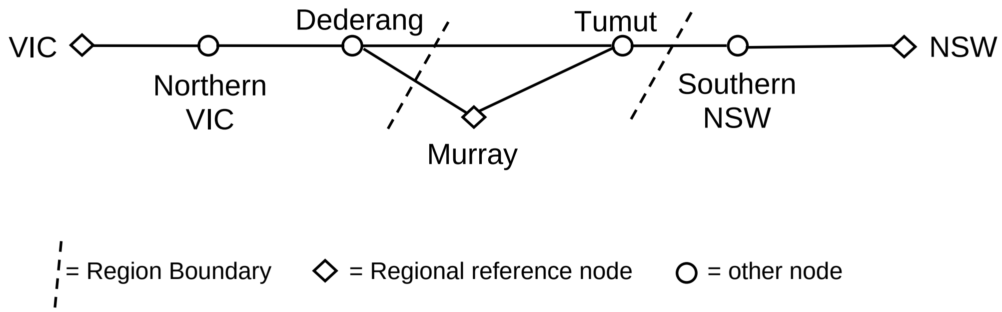

70. In this simple network, the correctly-oriented constraint equations reflecting the six physical network limits identified earlier, are set out in the table below. These constraint equations represent the physical limit on flows in the northwards direction. There is another set of six constraint equations (which are identical except the signs on all the coefficients are reversed) representing the physical limits on flows in the southwards direction.

Limit	Constraint equation
(1) V-NV	$-z_{NV} - z_D + F_{VIC\rightarrow SNY} \le K_1$
(2) D-M	$\frac{1}{3}z_G + \frac{1}{3}z_{UT} + \frac{1}{3}z_{LT} + \frac{2}{3}F_{VIC\rightarrow SNY} - \frac{1}{3}F_{SNY\rightarrow NSW} \le K_2$
(3) D-T	$-\frac{1}{3}z_G - \frac{1}{3}z_{UT} - \frac{1}{3}z_{LT} + \frac{1}{3}F_{VIC\rightarrow SNY} + \frac{1}{3}F_{SNY\rightarrow NSW} \le K_3$
(4) M-T	$-\frac{2}{3}z_G - \frac{2}{3}z_{UT} - \frac{2}{3}z_{LT} - \frac{1}{3}F_{VIC\rightarrow SNY} + \frac{2}{3}F_{SNY\rightarrow NSW} \le K_4$
(5) T-SN	$F_{SNY\rightarrow NSW} \le K_5$
(6) SN-N	$F_{SNY\rightarrow NSW} + z_{SN} \le K_6$

(here z_i refers to the "net injection" at node *i*, that is, the amount of power generated less the amount of power consumed at that node; F_l refers to the flow on the interconnector *l*)

51. Let's look first at the extent of mis-pricing. By inspection of the constraint equations above for this simple network we can see clearly that there is mis-pricing at:

(i) Upper and Lower Tumut whenever flows reach their physical limit on any of the links in the loop between Dederang, Murray and Tumut (constraints 2-4).

(ii) Remote intra-regional generators in NSW (the "western ring" generators) when flows reach their limit between southern NSW and NSW (constraint 6); and

(iii) Remote intra-regional generators in VIC when flows reach their limit between VIC and northern VIC (constraint 1).

71. The constraint equations that are used in the current NEM constraint library are (mostly) correctly formulated for this region/interconnector configuration. The following table shows the number of constraint equations which lead to mis-pricing of connection points in VIC, Snowy and NSW under the status quo. As can be seen a large number of constraint equations contribute to this mis-pricing:

Table 1: Number of constraint equations in the NEM which mis-price the given connection point

Connection Point	Code	Number of constraint equations
Lower Tumut	NLTS8	227
Upper Tumut	NUTS8	235
Murray	NMUR8	101[14]
Guthega	NGUT8	95
Bayswater	NBAY1	1791
Eraring	NEPS1	1844
Munmorah	NMNP1	1453
Mt Piper	NMTP1	1295
Wallerawang	NWW27	1320
Dartmouth	VDPS	360
Eildon	VEPS1	352
McKay Creek	VMKP1	361
West Kiewa	VWKP1	361

72. This mis-pricing is not a mere theoretical possibility. The following table, extracted from an earlier study on the prevalence of mis-pricing in the NEM, shows that virtually all of the connection points mentioned above were mis-priced for more than 200 hours in fiscal year 05/06:

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[14] Murray, being the regional reference node for the Snowy region should not be mis-priced under any constraint equations. However the current constraint library includes a number of constraints which previously were invoked when it was necessary to "reorient to Dederang" to avoid negative settlement residues. Interestingly this is not the only source of mis-pricing at Murray under the current constraint library. There are also a number of voltage stability constraints which mis-price Murray generation. Snowy Hydro makes reference to this point in their letter to the AEMC of 20 November 2006.

Connection Point (or group)	Duration of mis-pricing 2005-06 FY (hours)
Laverton PS	498.8
West Kiewa PS	238.9
McKay Ck PS	238.5
Dartmouth PS	231.3
Eildon PS	214.8
Hume PS (VIC share)	171.7
Yallourn PS units 2-4	169.9
Newport PS, Somerton PS	169.2
Upper Tumut PS	209.3
Lower Tumut PS	209.2
Bayswater PS, Liddell PS	208
Eraring PS units 3,4 (500 kV)	204.6
Munmorah PS, Vales Point PS	203.5
Eraring PS units 1,2 (330 kV)	204.6
Mt Piper PS, Wallerawang PS	197.9
Blowering, Hume (NSW share)	184.25
Murray	73.6
Guthega	70.4

73. As already noted, this mis-pricing has several undesirable consequences:

(a) this mis-pricing *reduces the short-term efficiency of dispatch*,[15] both between the mis-priced generators (since these generators no longer have an incentive to offer their output at a price which reflects their true cost) and, to an even greater extent, between competing generators located on different sides of a region boundary (since in this case, generators on one side of the region boundary have an incentive to offer their output at their true cost while competing generators on the other side of the region boundary can offer their output significantly above or below their true cost and still be dispatched).

(b) This mis-pricing *distorts location incentives,* particularly in the vicinity of region boundaries. For example, a high-cost new entrant may be able to locate in southern NSW where it can have access to the NSW RRP and where it has a reasonable chance of being dispatched, at the expense of Snowy generation located nearby on the other side of the region boundary. This is a concern which has been repeatedly emphasised by Snowy Hydro.

(c) As discussed below, this mis-pricing may give rise to negative settlement residues on both the VIC-Snowy interconnector and the Snowy-NSW interconnector.

74. In regard to hedging, recall from the earlier discussion that an inter-regional settlement residue arising on a notional interconnector will be non-firm when there is either a generator term or another interconnector term in the same constraint equation.

75. Looking at the constraint equations for the simple network above we see that 5 of the 6 constraint equations include terms involving both generators and interconnector. Whenever any of these constraints bind, the settlement residues will not be firm.

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[15] Strictly speaking, mis-pricing only reduces the efficiency of dispatch when RRP and the shadow nodal price at a generator's connection point are in a part of the SRMC curve of a generator which is not vertical. When the SRMC curve is vertical, the generator's elasticity of supply is zero, so changes in prices have no impact on changes in dispatch – mis-pricing is therefore not converted into dispatch inefficiencies.

76. In only one constraint equation (constraint 5) is there an interconnector term alone in the constraint equation. In only this case is the corresponding settlement residue "firm".

77. The same problem arises, of course, in the constraint equations used in the NEM dispatch engine. The following table shows the number of occasions when connection points in northern VIC, Snowy and NSW occur in the same constraint equation as the VIC-Snowy or Snowy-NSW interconnectors. As can be seen, there are a large number of constraint equations which include both generator terms and interconnector terms. In each of these cases the inter-regional settlement residues will not be firm. In some cases there may even arise negative settlement residues.

Table 2: Number of constraint equations which include both the listed connection points and either the VIC-Snowy or Snowy-NSW interconnector[16]

Connection Point	Code	With VIC-SNY	With SNY-NSW
Lower Tumut	NLTS8	44	171
Upper Tumut	NUTS8	43	178
Murray	NMUR8	21	80
Guthega	NGUT8	15	80
Bayswater	NBAY1	0	42
Eraring	NEPS1	0	23
Munmorah	NMNP1	0	0
Mt Piper	NMTP1	0	50
Wallerawang	NWW27	0	51
Dartmouth	VDPS	339	0
Eildon	VEPS1	333	0
McKay Creek	VMKP1	339	0
West Kiewa	VWKP1	339	0

78. Returning to the constraint equations for the simple network above, we see that in three of the six constraint equations (constraints 2-4) there are two or more interconnector terms and in two of these three equations the coefficients on the interconnectors have opposite sign. When these constraints bind, negative settlement residues *must* arise on at least one interconnector when flows on the interconnectors are in the same direction.

79. Again, we can further confirm these results by looking at the constraint equations used in the NEM. Inspection of the NEM constraint equations shows that there are 44 constraint equations in the current constraint library which include *both* the VIC-Snowy and Snowy-NSW interconnectors. The majority of these constraint equations relate to the Murray-Tumut constraint. When these constraints bind the VIC-Snowy and Snowy-NSW settlement residues will not be firm.

80. In 33 of these constraint equations, the VIC-Snowy and Snowy-NSW interconnectors have the opposite sign. As before, in these cases negative settlement residues *must* arise whenever one of these constraints is binding and the flow on the VIC-Snowy and Snowy-NSW interconnectors is in the same direction.

81. It is also possible to say something about the incentives on the larger generators to exercise any market power they might have. Specifically, we can observe that:

(i) Snowy Hydro has an incentive to use any market power it might have to bind constraints 1 and 2 in the northwards direction (between VIC and Northern VIC and between Dederang and Murray) and to unbind constraints 4,5 and 6 in the northwards direction.

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[16] This analysis was limited to constraint equations which have been clearly identified as being in the "option 4" form. Only the most recent version of each constraint equation was counted.

(Conversely, Snowy Hydro has an incentive to use any market power it might have to un bind constraints 1 and 2 in the southwards direction and to bind constraints 4,5 and 6).

(ii) Generators in NSW have an incentive to use any market power they might have to bind constraints 4,5 and 6 in the northwards direction (and conversely unbind in the southwards direction).

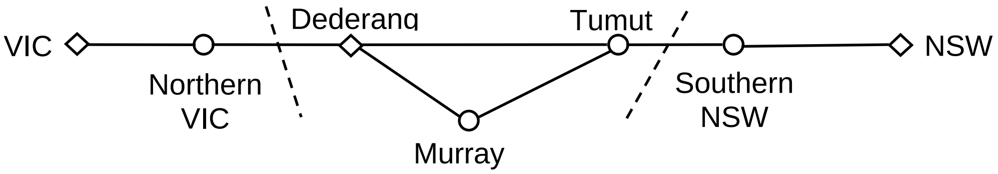
(iii) Generators in VIC have an incentive to use any market power they might have to unbind constraints 1, 2 and 3 in the northwards direction (and conversely, to bind these constraints in the southwards direction).

Option (B): Status quo, with Dederang in the Snowy region

82. Option (B) is the same as option (A) but with the Dederang connection point moved from the VIC region to the Snowy region and made the regional reference node for the Snowy region.

83. As with option A this configuration features three regions (VIC, Snowy, and NSW), and two interconnectors (VIC-Snowy and Snowy-NSW), but the regional reference nodes are now VIC, Dederang and NSW.

84. This option is very similar to the Snowy Hydro "reorientation" proposal considered recently by the Commission. The difference here is that under the latter proposal, reorientation was only proposed to occur when the Murray-Tumut constraint was binding or threatening to bind, whereas under this proposal, such "reorientation" would be permanent.



85. The revised constraint equations for this new network are set out below.

Limit	Constraint equation
(1) V-NV	$-z_{NV} + F_{VIC'\to SNY'} \le K_1$
(2) D-M	$-\frac{2}{3}z_M - \frac{1}{3}z_G - \frac{1}{3}z_{UT} - \frac{1}{3}z_{LT} + \frac{1}{3}F_{SNY'\to NSW} \le K_2$
(3) D-T	$-\frac{1}{3}z_M - \frac{2}{3}z_G - \frac{2}{3}z_{UT} - \frac{2}{3}z_{LT} + \frac{2}{3}F_{SNY'\to NSW} \le K_3$
(4) M-T	$\frac{1}{3}z_M + -\frac{1}{3}z_G - \frac{1}{3}z_{UT} - \frac{1}{3}z_{LT} + \frac{1}{3}F_{SNY'\to NSW} \le K_4$
(5) T-SN	$F_{SNY'\to NSW} \le K_5$
(6) SN-N	$F_{SNY'\to NSW} + z_{SN} \le K_6$

86. As can be seen by inspecting these new constraint equations, there is mis-pricing at northern VIC, southern NSW and Tumut, as before. Under these new equations, mis-pricing at Dederang (constraint 1) has been eliminated, but now there is mis-pricing at Murray whenever any network limit on the loop between Dederang, Murray and Tumut is binding (constraints 2,3 and 4).

87. In regard to hedging, we see that, as before, five out of six constraint equations include terms involving both generation and an interconnector, so as before, when these constraints bind, the inter-regional settlement residues are not firm.

88. However, there is reduction in the number of constraint equations which involve two or more interconnectors. Whereas previously there were three constraint equations which involved two or more interconnectors, this has reduced to none. There is, therefore, no risk of negative settlement residues arising from the loop flow problem. The "reorientation to Dederang" effect of this proposal eliminates the negative settlement residues arising from loop flow (negative settlement residues could still arise from the mis-pricing at any of the remote intra-regional connection points).

89. In regard to incentives to exercise market power, we can observe that:

(i) Snowy Hydro has an incentive to use its market power to bind constraint 1 in the northwards direction and to unbind constraints 2-6 in the northwards direction (and conversely, to bind constraints 2-6 and unbind constraint 1 in the southwards direction).

(ii) Generators in NSW have an incentive to bind constraints 2-6 in the northwards direction (and unbind in the southwards direction).

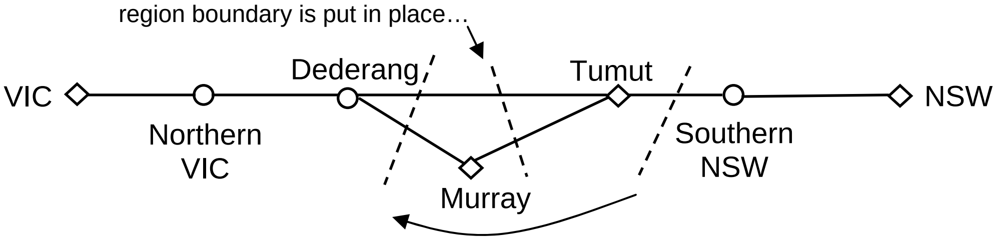
(iii) Generators in VIC have an incentive to unbind constraint 1 in the northwards direction (and bind in the southwards direction).

90. Finally, we can ask whether or not Murray and Tumut generation is made better off by this change in the region boundary. By comparing the price at the Dederang node relative to the price at the Murray node we can see that Snowy Hydro is made: better off (i.e., receives a higher price than it would receive under option A) when the Murray-Tumut constraint binds in the northerly direction and worse off when one of the other constraints on the loop (D-M, or D-T) binds in the northerly direction. The reverse is true when these constraints bind in the southerly direction. When one of the other constraints binds, Snowy Hydro is left no better or worse off.

Option (C)

91. Option (C) is the status quo with both of the existing congestion management mechanisms in place – the CSP/CSC derogation at Tumut and the Southern Generators' proposal.

92. In effect, the status quo can be viewed as a "dynamic region boundary change". In effect, when the Murray Tumut constraint binds, the CSP/CSC component ensures that Tumut receives its own price – i.e., is in its own region, as in option F. At other times, the region boundaries are as in option A. This is illustrated below:



At times when the Murray-Tumut constraint is binding, this region boundary is put in place…

…and the Snowy-NSW residues are used to offset the negative VIC-Snowy residues.

93. The pricing, hedging and dispatch outcomes under this approach are the same as under option A except in the case when the Murray-Tumut constraint is binding, in which case the constraint equations for option F apply. The outcomes under the constraint equations for option F are discussed in the corresponding section below.

94. As set out in the discussion of option A and option F, this approach leaves in place the mis-pricing at Dederang, other northern VIC connection points, and southern NSW. In addition, there is mis-pricing at Tumut if the Dederang-Murray or Dederang-Tumut constraints are binding. However, in the case where the Murray-Tumut constraint is binding, the mis-pricing at Tumut is eliminated.

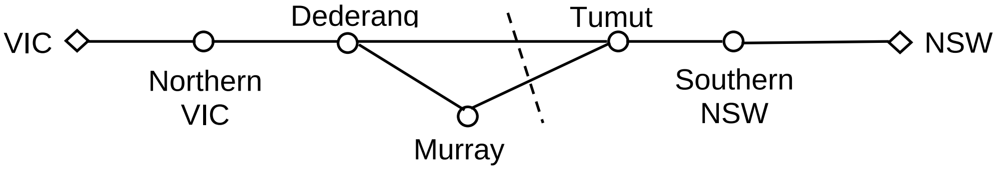
95. In terms of firmness of the inter-regional settlement residues, the VIC-Snowy settlement residues are not firm when constraints 1, 2 or 3 are binding. The Snowy-NSW settlement residues are not firm when constraints 2, 3 or 6 are binding. As with option A and option F, the Snowy-NSW residues are firm when constraint 5 is binding.

96. The firmness of the Snowy-NSW residues was carefully analysed in the Commission's final determination on the Southern Generator's proposal. The conclusion reached in that analysis was that the Southern Generator's proposal resulted in a form of "quasi-firmness". Specifically, it was determined that if market participants could predict in advance when this constraint would bind, they would be able to determine in advance the share of the Snowy-NSW residues they would need to purchase in order to obtain the hedge they required. However, it seems likely that it is difficult to predict when this constraint will bind. Therefore, the Snowy-NSW and VIC-Snowy residues are not firm when this constraint binds.

Option (D)

97. Option (D) is the Snowy Proposal, which involves abolishing the Snowy region and placing Murray generation in VIC and Tumut generation in NSW.

98. Under this option there are two regions (labeled VIC' and NSW') and a single interconnector (labeled $VIC' \rightarrow NSW'$). The regional reference nodes are at VIC and NSW.



99. The revised constraint equations for the simple network above are set out below.

Limit	Constraint equation
(1) V-NV	$-z_{NV} - z_D + -z_M + F_{VIC'\to NSW'} \le K_1$
(2) D-M	$-\frac{2}{3} z_M + \frac{1}{3} F_{VIC'\to NSW'} \le K_2$
(3) D-T	$-\frac{1}{3} z_M + \frac{2}{3} F_{VIC'\to NSW'} \le K_3$
(4) M-T	$\frac{1}{3} z_M + \frac{1}{3} F_{VIC'\to NSW'} \le K_4$
(5) T-SN	$z_G + z_{UT} + z_{LT} + F_{VIC'\to NSW'} \le K_5$
(6) SN-N	$z_G + z_{UT} + z_{LT} + F_{VIC'\to NSW'} + z_{SN} \le K_6$

100. By inspection of those constraint equations we can see that this option (D):

- Eliminates the mis-pricing at Tumut when any one of the constraints in the Dederang-Murray-Tumut loop binds.

- Introduces new mis-pricing of Tumut when constraints north of Tumut bind. Snowy Hydro expresses this in the following way:

> "Tumut is incentivised to maximise generation when the price in NSW is very high against any binding constraint into NSW".[17]

- Introduces new mis-pricing at Murray when constraints south of Dederang or in the Dederang-Murray-Tumut loop bind.

89. Under this option there are no constraint equations which include terms involving two or more interconnectors, so the problem of negative settlement residues due to loop flows has been eliminated. Snowy Hydro write:

> "Snowy Hydro's rule change proposal will in effect remove the impact of loop flows when the Murray to Tumut constraint binds"[18].

101. Eraring agree:

> "The Snowy Hydro proposal … appears to resolve the negative residue issues problems for VIC to Snowy flows".[19]

102. However, although the lack of firmness due to loop flow has been eliminated, overall the lack of firmness problem remains, and has possibly even been worsened:

- Under option A, five of six constraint equations included both interconnector and generator terms. Under this option, all six constraint equations include both interconnector and generator terms. Under the Snowy proposal the inter-regional

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[17] Snowy Hydro letter of 20 November 2006.

[18] Snowy Hydro, Rule Change Proposal, 11 November 2005.

[19] Eraring Energy, Submission to AEMC, 22 March 2006.

settlement residues are not firm under any binding constraints (compared to one constraint in option A).

- Under option D there are the same or more generator terms on the left hand side of the constraint equations. This is likely to make the inter-regional settlement residues even less “firm”.

103. As an aside, it is important to recognise that a mere reduction in the number of hedging instruments required to hedge between two locations does not imply that that hedging is easier or more effective. This is suggested by Snowy Hydro, who claim that a benefit of their proposal is that it:

> “Improves liquidity and ease of contract trade between the major load centres of Melbourne and Sydney (as only one instrument between NSW/VIC is required)”.[20]

104. In contrast, a reduction from two instruments to one may make hedging significantly less effective. What matters is not the number of hedging instruments but whether or not it is possible to form a portfolio of the available hedging instruments which perfectly hedges the risk of a given transaction. Given the number of different inter-regional trades that are possible, it is likely that reducing the number of hedging instruments (below some minimum) will make hedging harder and less effective, rather than easier.

105. In regard to incentives to exercise market power, we can observe that:

(i) Snowy Hydro now has major generating plant on both sides of the notional region boundary. Its incentives to bind or unbind the various constraints are no longer clear. It may be able to benefit from unbinding any of these constraints (and thereby enjoying uniform high prices at both Murray and Tumut) or binding any one of these constraints, thereby enjoying high prices at Tumut for northwards constraints or Murray for southwards constraints).

(ii) Generators in NSW have an incentive to bind each of these constraints in the northwards direction (and unbind these constraints in the southwards direction). Generators in VIC have the opposite incentive.

106. Finally, as before, we can ask whether or not Murray and Tumut generation is made better or worse off from a change to this option relative to option A. This is equivalent to asking whether or not the VIC price is higher than the Murray price (for Murray generation) and whether the NSW price is higher than the Murray price (for Tumut generation). By inspection of the equations above, we can see that:

(i) Murray generation is made better off when the Murray-Tumut constraint binds in the northerly direction and is made worse off when constraint 1, or constraints 2,3 bind (and conversely when these constraints bind in the southerly direction).

(ii) Tumut generation is made better off when constraints 5 and 6 bind in the northerly direction (and conversely when these constraints bind in the southerly direction).

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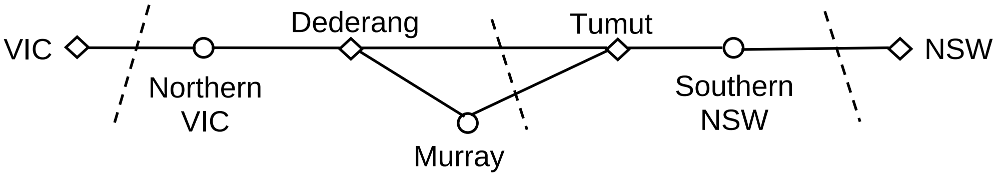
[20] Snowy Hydro, letter of 20 November 2006.

Option (E)

107. Option (E) is the Macquarie Generation proposal. This proposal both expands the Snowy region and divides it in two, as shown below:



108. Macquarie Generation propose that the regional reference node for the southern NSW region should be at Wagga. Locating the regional reference node at Wagga will almost certainly give rise to mis-pricing at Upper and Lower Tumut. Since one of the objectives of a region boundary change is to eliminate mis-pricing, it seems to me that it is essential to locate the regional reference node at Upper or Lower Tumut. In the analysis that follows I will assume that the regional reference node in the southern NSW region is at Lower Tumut. This makes this proposal appear more attractive. (The same analysis could also be carried out with the regional reference node at Wagga as originally proposed).

109. Therefore, under this option, there are four regions (labeled VIC', $NVIC'$, $SNSW'$ and NSW') and a three interconnectors (labeled $VIC' \to NVIC'$, $NVIC' \to SNSW'$, and $SNSW' \to NSW'$). The regional reference nodes are at VIC, Dederang, Tumut and NSW.

110. The revised constraint equations for this boundary/interconnector configuration (with the RRN in the southern NSW region at Lower Tumut) are set out in below:

Limit	Constraint equation
(1) V-NV	$F_{VIC' \to NVIC'} \le K_1$
(2) D-M	$-\frac{1}{3}z_G - \frac{2}{3}z_M + \frac{1}{3}F_{NVIC' \to SNSW'} \le K_2$
(3) D-T	$-\frac{2}{3}z_G - \frac{1}{3}z_M + \frac{2}{3}F_{NVIC' \to SNSW'} \le K_3$
(4) M-T	$-\frac{1}{3}z_G + \frac{1}{3}z_M + \frac{1}{3}F_{NVIC' \to SNSW'} \le K_4$
(5) T-SN	$-z_{SN} + F_{NVIC' \to SNSW'} \le K_5$
(6) SN-N	$F_{SNSW' \to NSW'} \le K_6$

111. From inspection of these constraint equations we can observe, in regard to mis-pricing that:

- The mis-pricing at both the Tumut nodes is eliminated (by the choice of RRN).
- The mis-pricing at northern VIC is eliminated.
- New mis-pricing is introduced at Murray whenever any constraints reflecting the limits in the Dederang-Murray-Tumut loop are binding.

112. In regard to hedging, now there are two out of six constraint equations which include only a single interconnector term on the left hand side. When these constraints bind, the inter-regional settlement residues will be as firm as the constraint right-hand-side. For these constraint equations, at least, this proposal has increased the firmness of the settlement residues. However, it is useful to recall that this simple model is a highly stylized reflection of the real constraints in the NEM, especially in its representation of the NSW and VIC regions. It is unlikely that this proposal will, in practice, lead to any material increase in the firmness of residues when constraints corresponding to what I have referred to here as V-NV or SN-N constraints bind.

113. None of the constraint equations include more than a single interconnector term, so the problem of negative settlement residues due to loop flow is eliminated. Macquarie Generation write:

> "by reducing the likelihood of counter-price flows in this part of the NEM, the proposal would increase the 'firmness' of settlement residue auction units. This would improve the value of these units and make them a more effective tool for participants to manage inter-regional trading risks. At the same time, it would reduce the need for NEMMCO to devise artificial solutions to minimise the incidence of negative residues".[21]

100. Macquarie Generation is correct that this proposal would reduce the need to "devise artificial solutions to minimise the incidence of negative residues" but it would not lead to firm inter-regional settlement residues. In four constraint equations there are both interconnector terms and generator terms. When these constraints bind, the inter-regional settlement residues will not be firm. As Snowy Hydro claim:

> Under this proposal "basis risk still exists for generators in these new regions trying to access the load rich NSW and VIC regions". [22]

114. In regard to incentives to exercise market power, we can observe that:

(i) As under the Snowy proposal, the net incentive on Snowy Hydro is unclear. It may be able to benefit from unbinding constraints 2-5 (thereby enjoying uniform high prices at both Murray and Tumut) or binding any one of these constraints, thereby enjoying high prices at Tumut for northwards constraints or Murray for southwards constraints).

(ii) Generators in the "southern NSW" region (apart from Snowy Hydro) have an incentive to bind each of the constraints 2-5 in the northwards direction (and unbind these constraints in the southwards direction). Such generators also have an incentive to unbind constraint 6 in the northward direction (and to bind the same constraint in the southwards direction). Snowy Hydro says that under this option "headroom incentives remain and thus dis-benefits to NSW customers would be entrenched".

(iii) Generators in the "northern VIC" notional region (apart from Snowy Hydro) have an incentive to unbind the constraints 2-5 in the northwards direction and to bind constraint 1 (and the opposite for the southwards direction).

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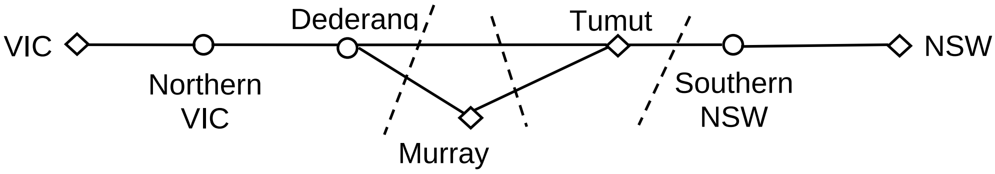
[21] MacGen Rule Change Proposal, 10 February 2006.

[22] There is an outstanding question about the MacGen proposal whether or not loop-flow is created visa the Murraylink interconnector. Westpac note: "It is important to recognise that the suggested typology is not strictly radial and thus loop flows can still occur. It is not 100% certain that the proposal will eliminate negative residue nor even reduce its frequency". Westpac, Submission to the AEMC, 24 March 2006.

Option (F)

115. Option (F) is the Eraring submission option, which essentially requires dividing the Snowy region.



116. Under this option, there are four regions (labeled VIC, MUR, TMT and NSW) and a three interconnectors (labeled $VIC \rightarrow MUR$, $MUR \rightarrow TMT$, and $TMT \rightarrow NSW$). The regional reference nodes are at VIC, Murray, Tumut and NSW.

117. The correctly oriented constraint equations for this boundary/interconnector configuration are as follows:

Limit	Constraint equation
(1) V-NV	$-z_{NV} - z_D + F_{VIC \rightarrow MUR} \leq K_1$
(2) D-M	$\frac{1}{3} z_G + \frac{2}{3} F_{VIC \rightarrow MUR} - \frac{1}{3} F_{MUR \rightarrow TMT} \leq K_2$
(3) D-T	$-\frac{1}{3} z_G + \frac{1}{3} F_{VIC \rightarrow MUR} + \frac{1}{3} F_{MUR \rightarrow TMT} \leq K_3$
(4) M-T	$-\frac{2}{3} z_G - \frac{1}{3} F_{VIC \rightarrow MUR} + \frac{2}{3} F_{MUR \rightarrow TMT} \leq K_4$
(5) T-SN	$F_{TMT \rightarrow NSW} \leq K_5$
(6) SN-N	$F_{TMT \rightarrow NSW} + z_{SN} \leq K_6$

118. From inspection of the constraint equations we can see that:

(a) In regard to mis-pricing, the mis-pricing at the Tumut nodes is eliminated (in practice, there may remain a small amount of mis-pricing at either Upper or Lower Tumut since these two connection points have slightly different coefficients in the constraint equations). The mis-pricing of generators in NSW and in VIC remains. The potential for this mis-pricing to induce negative settlement residues remains.

As is always the case, this mis-pricing may give rise to dispatch inefficiencies. This problem has been emphasised by Snowy Hydro who write:

> "Tumut has 1600 to 1700 MW of unconstrained access to NSW. However, due to the Snowy regional boundary it does not compete on equal footing with "western ring" generators. While the "western ring" generators can bid negative or very low prices as they receive the high Sydney West price. Tumut generation receives its bid price (local nodal price) and therefore has incentives to bid at the

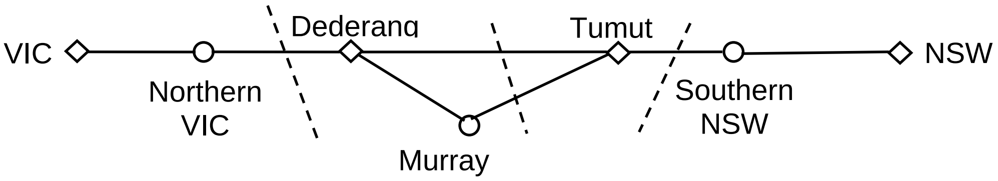
lower end of its available capacity of 1600 MW in order to secure access to NSW price and mitigate any basis price risk with contracts written on the NSW RRN".[23]

(b) In regard to hedging, since constraints 2, 3 and 4 have two interconnector terms on the left-hand side (and in the case of constraints 2 and 4, with opposite sign), the problem of negative settlement residues due to loop-flow remains. Due to the presence of generator terms on the left hand side in all constraint equations except 5, it is likely that none of the VIC-Murray, Murray-Tumut or Tumut-NSW residues are firm, except the Tumut-NSW residues and then only when only constraint 5 is binding.

(c) In regard to the behaviour of Snowy Hydro, we can predict that Snowy Hydro has an incentive to use any market power at Murray to bind constraints 1 and 2 in the northward direction and to unbind constraints 3 and 4 in the northward direction. Similarly, Snowy Hydro has an incentive to use any market power at Tumut to bind constraint 3 and 4 and to unbind constraints 5 and 6 (again, in the northward direction). The incentives are opposite for the southwards direction.

Option (G)

119. Option (G) is the Split Region option, with the regional reference node of the Murray region at Dederang. This proposal amounts to the combination of (a) the CSP/CSC derogation at Tumut and (b) Snowy's "reorientation" proposal; except that under this option, these mechanisms would be made permanent, applying under all constraints, not just when the Murray-Tumut constraint binds.



120. As under option F, there are four regions (VIC, MUR, TMT and NSW) and three interconnectors ($VIC \to MUR$, $MUR \to TMT$, and $TMT \to NSW$) but now the regional reference nodes are at VIC, Dederang, Tumut and NSW.

121. The correctly oriented constraint equations for this option are as follows:

Limit	Constraint equation
(1) V-NV	$-z_{NV} + F_{VIC\to MUR} \le K_1$
(2) D-M	$\frac{1}{3}z_G + \frac{2}{3}z_M + \frac{1}{3}F_{MUR\to TMT} \le K_2$
(3) D-T	$-\frac{1}{3}z_M - \frac{2}{3}z_G + \frac{2}{3}F_{MUR\to TMT} \le K_3$
(4) M-T	$\frac{1}{3}z_M - \frac{1}{3}z_G + \frac{1}{3}F_{MUR\to TMT} \le K_4$

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[23] Snowy Hydro, Rule change proposal, 11 November 2005.

(5) T-SN	$F_{TMT \to NSW} \le K_5$
(6) SN-N	$F_{TMT \to NSW} + z_{SN} \le K_6$

122. By inspection of these constraint equations we see that the outcomes under this approach are the same as in option (G) except that:

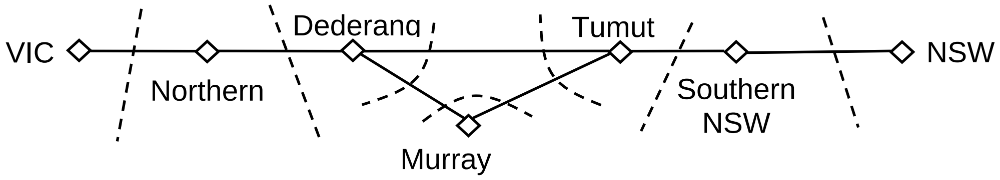
(a) In regard to mis-pricing, the Murray connection point is now mis-priced. The mis-pricing of generators in NSW and in VIC remains. The potential for this mis-pricing to induce negative settlement residues remains.

(b) In regard to hedging, the problem of negative settlement residues due to loop-flow is eliminated. However, it remains likely that none of the VIC-Murray, Murray-Tumut or Tumut-NSW residues are firm, except in the case of Tumut-NSW flows when only constraint 5 is binding.

(c) In regard to the incentives on Snowy Hydro to exercise its market power, as under options D and E, the net incentive on Snowy Hydro is unclear. It may be able to benefit from unbinding constraints 2-4 (thereby enjoying uniform high prices at both Murray and Tumut) or binding any one of these constraints, thereby enjoying high prices at Tumut for northwards constraints or Murray for southwards constraints).

Option (H)

123. Option (H) represents a hypothetical network in which there is full nodal pricing and the interconnectors have been chosen to reflect the physical location of the transmission links. This network, therefore, reflects as closely as possible the physical network reality. Does representing the network in this way eliminate the mis-pricing and hedging problems?



124. Under this option, there are seven regions (labeled V, NV, D, M, T, SN and N) and seven interconnectors (labeled $V \to NV$, $NV \to D$, $D \to M$, $D \to T$, $M \to T$, $T \to SN$, and $SN \to N$). Each of the seven nodes in the network above is a regional reference node.

125. The constraint equations for this option are set out below:

Limit	Constraint equation
(1) V-NV	$F_{V \to NV} \le K_1$
(2) D-M	$F_{D \to T} - F_{M \to T} \le K_2$

(3) D-T	$-F_{D\to M} - F_{M\to T} + 2F_{D\to T} \leq K_3$
(4) M-T	$-F_{D\to M} + F_{D\to T} \leq K_4$
(5) T-SN	$F_{T\to SN} \leq K_5$
(6) SN-N	$F_{SN\to N} \leq K_6$

126. By inspection of these constraint equations we can see that *all* generator mis-pricing has been eliminated.

127. In addition, for the three constraints corresponding to the "radial" parts of the network, (constraints 1, 5 and 6), the corresponding constraint equation has only a single interconnector term on the left hand side. For these three constraint equations, the inter-regional settlement residue is a firm instrument for hedging inter-regional trading. (As before, recall that this simple model is an imperfect reflection of the real network in these regions and therefore it is unlikely that a boundary/interconnector configuration of this kind could eliminate mis-pricing and lead to firm inter-regional settlement residues except for possibly a limited number of constraints without a significantly larger number of regions)

128. However, we can see that in the vicinity of the loop in the network, there remain two or more interconnectors on the left-hand-side of the correctly oriented constraint equations. As a result, the inter-regional settlement residues when these constraints bind will not be firm. In addition, since in every case the coefficients on the interconnector terms have opposite sign, it follows that there is a real risk of negative settlement residues arising.

129. The following table summarises this analysis of the options. This table shows, for each option, which connection points are mis-priced and/or which residues are non-firm under each of the physical constraints:

Table 3: Summary of the Pricing and Hedging Implications of each Option

	Constraint 1		Constraints 2-4		Constraint 5		Constraint 6	
Option:	Nodes Mis-priced	I/Cs non-Firm	Nodes Mis-priced	I/Cs non-Firm	Nodes Mis-priced	I/Cs non-Firm	Nodes Mis-priced	I/Cs non-Firm
A	NV, D	VIC-SNY	T	VIC-SNY, SNY-NSW	None	None	SN	SNY-NSW
B	NV	VIC-SNY	M, T	SNY-NSW	None	None	SN	SNY-NSW
C	D, NV	VIC-SNY	2,3: T 4: None	2,3: VIC-SNY, SNY-NSW 4: quasi-firm	None	None	SN	SNY-NSW
D	NV, D, M	VIC-NSW	M	VIC-NSW	T	VIC-NSW	T, SN	VIC-NSW
E	None	None	M	NVIC-SNSW	SN	NVIC-SNSW	None	None
F	NV, D	VIC-MUR	None	VIC-MUR, MUR-TMT	None	None	SN	TMT-NSW
G	NV	VIC-MUR	M	MUR-TMT	None	None	SN	TMT-NSW
H	None	None	None	D-M, M-T	None	None	None	None

What conclusions can we draw?

130. Region boundary changes are a very blunt instrument for addressing the mis-pricing and hedging problems noted above. None of the proposals considered above solve all of the mis-pricing and hedging problems in and around the Snowy region. In fact there is no region boundary change which will solve the pricing and hedging problems in and around the Snowy region. All of the region-boundary-change-only options, while resolving some problems, will worsen other problems.

131. The methodology set out here is not well suited to make judgments about trade-offs between imperfect alternatives.

132. It is possible to correct both the mis-pricing and hedging problems in and around the Snowy region, however doing so would require the implementation of a congestion-management mechanism. This mechanism would need to be applied not just to generation in the Snowy region, but also to generation in NSW and VIC. Such a mechanism would seek to simultaneously ensure that each generator faced a correct price for its output and that each generator was able to obtain the firm hedge that it desired.

133. If such a mechanism were implemented the market significance of the region boundaries would be diminished. There would remain some significance of the region boundaries for the demand side – especially for ensuring adequate incentives for responding to short-term price signals and for longer term location decisions. One conclusion emerging from this analysis is that it may be necessary to correctly price load in order to achieve the firmness of the settlement residues necessary for effective inter-regional hedging.

134. This analysis does not yield grounds for the view that either the Snowy Hydro or the Macquarie Generation proposals will be an improvement over the status quo. The problems with the status quo cannot be solved with a region boundary change alone.

Appendix: Transformations to the constraint equations necessary to implement each option

135. For a given constraint equation, let α_i and β_l be the coefficients on the *i*th connection point and the *l*th interconnector under the status quo. Let α_i' and β_l' be the coefficients in the transformed constraint equation following the region boundary change.

136. Option (B) shifts the Dederang node into the Snowy region and makes it the RRN for the Snowy region. The changes necessary to the constraint equations are as follows:

$$\beta'_{VIC'\to SNY'} = -\alpha_{DDG}$$

$$\beta'_{SNY'\to NSW} = \beta_{SNY\to NSW} + (\beta_{VIC\to SNY} + \alpha_{DDG})$$

$$\alpha'_{MUR} = \alpha_{MUR} - (\beta_{VIC\to SNY} + \alpha_{DDG})$$

$$\alpha'_{GUT} = \alpha_{GUT} - (\beta_{VIC\to SNY} + \alpha_{DDG})$$

$$\alpha'_{UT} = \alpha_{UT} - (\beta_{VIC\to SNY} + \alpha_{DDG})$$

$$\alpha'_{LT} = \alpha_{LT} - (\beta_{VIC\to SNY} + \alpha_{DDG})$$

$$\alpha'_{DDG} = 0$$

137. All other coefficients remain as they are in the status quo.

138. Option (C) is not covered here since it represents a combination of option A and option (F).

139. In the case of option (D), the Snowy proposal, the changes to the constraint equations required are as follows:

$$\beta'_{VIC'\to NSW'} = \beta_{VIC\to SNY} + \beta_{SNY\to NSW}$$

$$\alpha'_{MUR} = \alpha_{MUR} - \beta_{VIC\to SNY}$$

$$\alpha'_{GUT} = \alpha_{GUT} + \beta_{SNY\to NSW}$$

$$\alpha'_{UT} = \alpha_{UT} + \beta_{SNY\to NSW}$$

$$\alpha'_{LT} = \alpha_{LT} + \beta_{SNY\to NSW}$$

140. In the case of option (E), the MacGen proposal, the changes to the constraint equations required are as follows:

$$\alpha'_{NV} = \alpha_{NV} - \alpha_{D}$$

$$\alpha'_{GUT} = \alpha_{GUT} - \alpha_{D} - \beta_{VIC\to SNY}$$

$$\alpha'_{UT} = \alpha_{UT} - \alpha_{W}$$

$$\alpha'_{LT} = \alpha_{LT} - \alpha_{W}$$

$$\alpha'_{MUR} = \alpha_{MUR} - \alpha_{D} - \beta_{VIC \to SNY}$$

$$\alpha'_{SN} = \alpha_{SN} - \alpha_{W} - \beta_{SNY \to NSW}$$

$$\beta'_{VIC' \to NVIC'} = -\alpha_{D}$$

$$\beta'_{NVIC' \to SNSW'} = \alpha_{D} - \alpha_{W} + \beta_{VIC \to SNY}$$

$$\beta'_{SNSW' \to NSW'} = \alpha_{W} + \beta_{SNY \to NSW}$$

$$\alpha'_{D} = 0$$

$$\alpha'_{W} = 0$$

141. Under option (F), the Eraring submission option, the changes to the constraint equations required are as follows:

$$\beta'_{VIC \to MUR} = \beta_{VIC \to SNY}$$

$$\beta'_{MUR \to TMT} = -\alpha_{LT}$$

$$\beta'_{TMT \to NSW} = \beta_{SNY \to NSW} + \alpha_{LT}$$

$$\alpha'_{UT} = \alpha_{UT} - \alpha_{LT}$$

$$\alpha'_{LT} = 0$$