Project Energy Connect Implementation Paper

November 2022

Market integration including dispatch and settlements residue auction

Important notice

Purpose

The purpose of this document is to inform stakeholders of the market integration arrangements for Project EnergyConnect, a new phyiscal interconnection between New South Wales and South Australia. AEMO also seeks feedback from stakeholders on options for amending the Settlements Residue Auction (SRA) to accommodate Project EnergyConnect.

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Version control

Version	Release date	Changes
1	14/11/2022	Initial version.

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Executive summary

Project EnergyConnect (PEC) will establish a new major physical transmission connection between South Australia and New South Wales, with an additional interconnection between Buronga (New South Wales) and Red Cliffs (Victoria). The interconnection of these three regions will establish a loop flow across these three National Electricity Market (NEM) regions.

AEMO's Integrated System Plan[1] notes the advised delivery date for PEC is July 2026. While PEC will be developed in two phases, this paper assumes the first phase will be implemented as an incremental increase in the capacity of the existing interconnection between Victoria and South Australia.

This paper covers an overview of PEC, key considerations for PEC, consultation on the management of negative residues from PEC, and the timeline for consultation.

Key considerations

PEC presents a number of challenges for integration into the NEM. These are:

- Loop flows formed by PEC operating in parallel with Victoria-New South Wales Interconnector, Murraylink and the Heywood interconnector in the central dispatch process.
- Regonal boundaries and interconnectors with PEC.
- Modelling interconnector marginal loss equations in the central dispatch process.
- Managing inter-regional settlements residues and designs for the Settlements Residue Auction.

AEMO is considering whether Phase 1 will require any other technical changes that will be required for the completed PEC. These considerations are not the subject of this consultation.

Timeline for the review

This review is being conducted in one round of consultation. Following consultation, AEMO will prepare and publish a summary of feedback and report to the Settlements Residue Committee to commence a program to change the settlement residue auction (SRA) arrangements (including any SRA rule changes, if required).

AEMO welcomes stakeholder feedback on this paper. Written feedback can be provided by email to StakeholderRelations@aemo.com.au and is requested by 19 January 2023.

[1] AEMO. Integrated System Plan. 2022-integrated-system-plan-isp.pdf (aemo.com.au)

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1 Introduction

1.1 Purpose and context for this paper

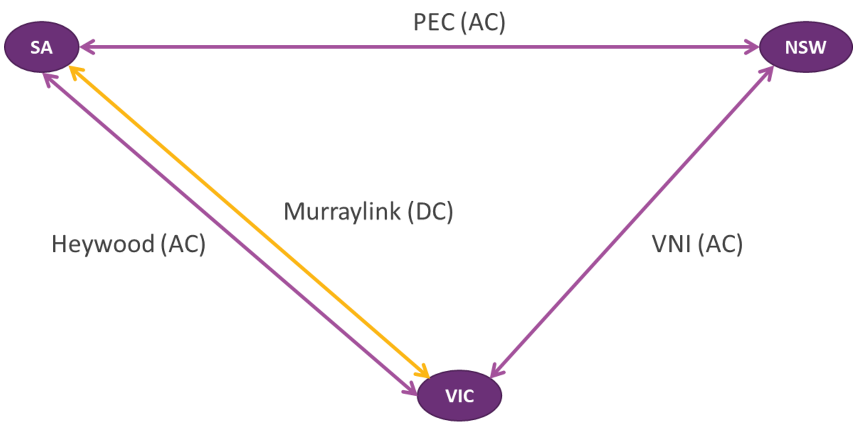
This paper provides an overview of the Project Energy Connect (PEC) transmission interconnector, including specific market integration activities required ahead of commissioning and energisation.

PEC will establish a new major physical transmission connection between South Australia and New South Wales, with an additional interconnection between Buronga (New South Wales) and Red Cliffs (Victoria). The interconnection of these three regions will establish a loop flow across these three National Electricity Market (NEM) regions[2].

Information about PEC in the context of current NEM topology, as well as potential changes to dispatch, constraints, loss model and the settlements residue auction (SRA), is provided. Stakeholder feedback is sought on options outlined for amendments to the SRA to accommodate PEC.

There are important considerations relating to how the physical transmission asset of PEC is treated and integrated from a markets perspective, and more particularly the network topology upon which the National Electricity Market Dispatch Engine (NEMDE) is based (Figure 1). This has important implications for dispatch, pricing, network flows and settlements residue (management as well as auctions). This paper provides an overview and introduction to the key issues, outlines the range of options under consideration to address these issues and proposes a path forward for the treatment of PEC as relating to the NEM's dispatch, flow management and market design, including any considerations of project staging.

Figure 1 PEC region structure



[2] Marinus link may also have loop flow implications that would need to be considered as part of its implementation.

1.2 Project Energy Connect overview

1.2.1 Introduction to Project Energy Connect

PEC is an electricity transmission project to deliver a physical interconnection between the power networks of South Australia and New South Wales, to be constructed jointly by Electranet and Transgrid[3]. The project will involve a 900 km, 330 kilovolt (kV) transmission line from Wagga Wagga in New South Wales to Robertstown in South Australia, via Buronga. The project will also provide a connection between Buronga in New South Wales to Red Cliffs in Victoria. In total, the project will provide approximately 800 megawatts (MW) of transmission capacity between New South Wales and South Australia power networks, expected to be delivered in two phases[4] (see Figure 2):

- PEC phase 1 (150 MW bi-directional capacity). The first phase will comprise the connection between Robertstown and Buronga. Capacity release 1 July 2024.
- PEC phase 2 (combined transfer limit across Heywood and PEC interconnectors: 1,300 MW import into South Australia; and 1,450 MW export). The second phase comprises the connection between Buronga to Wagga Wagga. Full capacity release is currently expected 1 July 2026.

Figure 2 Project Energy Connect route

Source: Project Energy Connect Fact Sheet, 31 August 2022, available at https://www.projectenergyconnect.com.au/download.php?id=8.

[3] Refer project website: https://www.projectenergyconnect.com.au/index.html.

[4] Expected milestones are as outlined in the 2022 ESOO: https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2022/2022-electricity-statement-of-opportunities.pdf?la=en

2 Loop flows

Transmission networks that interconnect with other systems will experience a phenomenon called loop flows. The construction and market integration of PEC will establish a loop flow between South Australia, New South Wales and Victoria.

2.1 Overview of loop flows and the 'spring washer' effect

Loop flows occur when some portions of scheduled power are distributed into other branches that are adjacently connected due to a transmission constraint, as power flow is strictly governed by Kirchoff's Law.

As the loop flow behaviours of a system mainly depends on the network topology, any alterations or augmentations to the interconnected transmission network, such as PEC, can influence the occurrence or frequency of loop flows.

One particular phenomenon that has the potential to occur in a topology with loop flows is known as the 'spring washer' effect, an unusual pricing characteristic which can be observed between nodes connected in a loop flow. Specifically, this effect is characterised by large, inconsistent pricing variations affecting adjacent nodes within a constrained loop network. This may materialise as price spikes affecting nodes that are situated along a constrained transmission line, followed by decreasing prices when heading towards the original node. Resultantly, prices may be very high at one node versus negative at just the adjacent node within the loop.

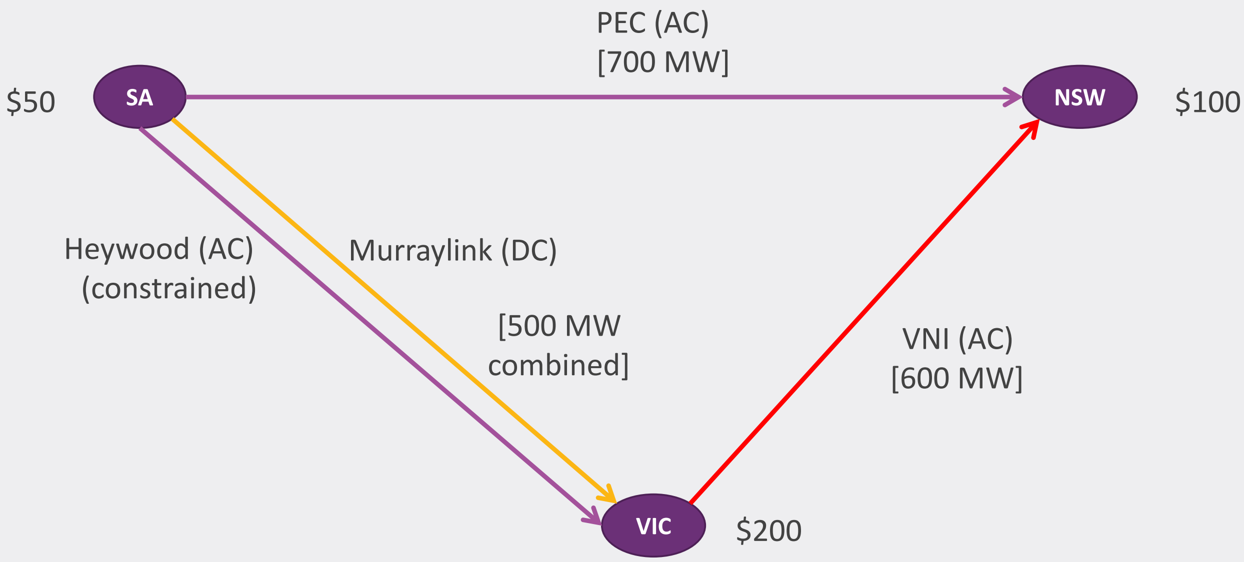
This effect is observed in nodal pricing models present in international jurisdictions such as New Zealand, the United States and Europe (refer Section 2.2). Appendix A1 provides further contextual reference material regarding loop flows and the 'spring washer' effect.

The introduction of PEC into dispatch as per the 'Interconnector' model (refer Section 3.2) would be subject to these same 'spring washer' price impacts, with the potential to result in unexpected negative settlement residue (NSR) conditions.

Considering this, the current management approach (involving operational intervention to cap the interconnector, further described in Section 3.5) is arguably not feasible for addressing NSR associated with the PEC 'spring washer' effect. The treatment and allocation of residues also has important implications for the settlement residue auction (SRA). As such, Section 4.2 proposes a range of alternatives for managing NSR in the context of a NEM topology with loop flows.

An example of the PEC 'spring washer' effect in the NEM

An example is provided based on the 'Interconnector' model with flow from South Australia to Victoria and to New South Wales*. If the Heywood interconnector is at a limit, prices and flows will be as shown with power flowing from a high-priced region (Victoria) to a lower priced region (New South Wales). This is known as a counter-price flow, with the 'spring washer' effect being observed with high and low prices being observed on either side of the South Australia – Victoria constraint. The counter price flow between Victoria and New South Wales would amount to negative residues of -$60k, although the overall solution would still maintain net positive residues (South Australia – Victoria +$75k, South Australia – New South Wales +$35k).



Under an alternative 'Micro-slice' model (refer Section 3.2), the prices and dispatch outcomes would in theory be identical regardless of the pricing model, but depending on the relative flows between the regions, residues could become net negative. (In the example above, the PEC flow would be attributed to the South Australia – Victoria and Victoria – New South Wales).

**(Example provides illustrative flows and prices only; ignores effect of losses.)*

2.2 International examples

The management of loop flows is an important operational consideration for many international electricity markets, most relevantly for liberalised market regimes operating under a security constrained economic dispatch (SCED). This can occur across international boundaries, such as with the European electricity market, or within country or state boundaries.

In the international domain, the problem emerges typically in market regions with either multiple price zones or markets (where a circuit loop is present in the market network topology) or in markets that have implemented locational marginal pricing (LMP) to the node. In each case, the adopted approaches to the management of loop flows in each of these regions has reflected the network topology and the impacts of such on market pricing, schedules and dynamics.

New Zealand

The New Zealand electricity market is likely the most apposite international example of loop flows that have applicability to the NEM. New Zealand operates a nodal electricity market with approximately 285 nodes. While the 'spring washer' effect is a recognised consequence of a locational congestion model, particular procedures exist for 'high spring washer' conditions[5]. A high spring washer price situation is defined by the Electricity Industry Participation Code 2010 (NZ) as a trading period where one or more AC security constraints bind and the nodal price at any one node is at least five times greater than the highest unconstrained cleared offer price. This situation tends to trigger during high demand conditions where congestion is present across areas of the network. Importantly, the procedure in place applies to pricing post fact, meaning that dispatch occurs and pricing adjustments are made by the system operator for the prior trading day. This differs to the current constraint clamping procedures in the NEM relating to counter price flows. The adjustment made by the system operator is to relax the binding constraint by 1 MW in a repetitive manner until the high spring washer condition cease to exist. The effect of this ex-post procedure is to limit the impact of extreme price differentials in the market, acting in effect like a price spread exposure cap rather than a real-time constraint relaxation procedure.

United States

Many US markets have implemented LMP, and loop flows are prevalent given the nodal topology. In most instances loop flows within regions are of much less concern, and in general they are an accepted part of nodal pricing. The specific challenges in these markets tend to relate to managing the flows across regional boundaries. For example, in 2008 two US independent system operators (ISO) – the Midwest ISO and Pennsylvania, New-Jersey Maryland (PJM) ISO – investigated loop flows at several interfaces at interfacing regions, most notably relating to flows around Lake Erie[6]. The bulk of electricity flowed counter-clockwise but from mid-2007 flows began reversing. A key challenge relating to this, and more broadly in US nodal markets, is the distinction between physical flows and scheduled flows (both in real-time markets and also the day-ahead auction, through which much electricity is traded). When counter-price flows occur, this creates congestion and has a significant impact on electricity market participants, which have financial settlements based on a day-ahead dispatch. Congestion was recorded mainly in the New York Independent System Operator (NYISO) region, resulting in higher charges, which lead to a non-public investigation of the same issue by the US Federal Energy Regulatory Commission (FERC)[7]. Operational response to loop flows in the US include 'transmission-loading reliefs' which are an ad-hoc and non-trans emergency procedure to maintain system security and avoid resource or line overloading. The issue can be further complicated by the specific approaches adopted by an ISO to inter-regional settlement – sometimes based on less granular non-physical path-based or wheeling approaches to allocating congestion charges. Market manipulation is also a concern, although in the Lake Erie case, FERC found no

[5] Transpower, 'GL-RR-448 Resolving Infeasibilities and high spring washer price situation – An Overview', at https://www.transpower.co.nz/sites/default/files/bulk-upload/documents/GL-RR-448%20Resolving%20Infeasibilities%20and%20high%20spring%20washer%20price%20situation%20-%20An%20Overview.pdf.

[6] PJM, Midwest-ISO 'Investigation of Loop Flows Across Combined Midwest ISO And PJM Footprint: Phase II' (2008), at https://www.miso-pjm.com/~/~/media/6A3A3B32A0E54EED877E5EFBE9846DA4.ashx.

[7] Reuters, 'FERC investigates NY power 'loop flow' issue' August 23 (2008), at https://www.reuters.com/article/utilities-nyiso-ferc-idUSN2229443720080822.

evidence of such[8]. The long-term solution in this case was a revised inter-regional pricing methodology. In the absence of a physical day-ahead market in the NEM, the issue of inter-temporal settlement will not arise.

As indicated above, in general, loop flows are not a major cause of intervention of the nodal topology within ISO regions. However, where concerns tend to arise for loop flows in US is at the borders or interties (interconnectors) between regions. The methodology for scheduling flows as between regions is co-ordinated between the governing ISOs and disparities can arise between the physical flows and market schedules. As such, intervention is focused upon solutions that better reflect the physical dynamics of inter-regional flows.

Europe

In Europe, loop flows have been an important issue in the European day-ahead market. The divergence between physical and scheduled flows is exacerbated by the abstraction introduced by regional bidding zones in the day-ahead market[9]. Loop flows under congestion are of particular concern in the German-Austrian common bidding zone and surrounding regions including Poland, Hungary and Czech Republic. This is not altogether unexpected because of the high level of network abstraction adopted in the day-ahead market. Greater network investment and flow-based market coupling are the solution pathways that have been adopted in Europe.

In summary, Table 1 summarises the operational approaches adopted by international jurisdictions to manage loop flows and spring washer conditions.

Table 1 Summary of international examples managing loop flows

Issue	Period	Jurisdiction	Approaches
New Zealand	Ongoing	Transpower	Ex-post relaxation of pricing to reduce high spring washer condition impacts.
Lake Erie loop flows	2007-09	US (PJM, MISO, NYISO)	Revised regional pricing methodology and modified contract flow paths.
Europe day-ahead market	2013-current	Europe	Implementation of flow-gate pricing, bidding zone reconfiguration. Potential shift towards nodal pricing.

Based on international examples above, one of the challenges associated with loop flows occurs when there is a mismatch between actual flows as driven by the physics of AC electricity networks, and the market-based approximation of those physical flows. The network approximation of nodal markets is a closer approximation of reality relative to zonal markets, which tend to rely upon power flow-based approximations of intra-regional flows. While some physical-market mismatches are inevitable with a zonal model, it does not necessarily invalidate the selected approach as it is difficult and arguably impossible to design a framework that wholly accounts for all unanticipated outcomes.

[8] Pepper T 'FERC Finds No Market Manipulation in Lake Erie Loop Flow Problem' (2009), at https://www.troutmanenergyreport.com/2009/07/ferc-finds-no-market-manipulation-in-lake-erie-loop-flow-problem/.

[9] Thema Consulting, 'Loop flows – Final advice – prepared for the European Commission' (2013), at https://ec.europa.eu/energy/sites/ener/files/documents/201310_loop-flows_study.pdf.

3 Implementation considerations for the NEM

3.1 Reflecting loop flows in the NEM

PEC will establish a new major physical transmission connection between South Australia and New South Wales. This new interconnector brings together the first AC transmission 'loop' across regulated interconnectors in the NEM, represented by the South Australia, New South Wales and Victoria regions. AEMO intends to reflect the new major physical transmission connection in the network model for dispatch, creating a new interconnector between New South Wales and South Australia. This would create a network loop between the regional nodes of South Australia, Victoria and New South Wales, where none previously existed in the dispatch network topology, introducing important implications for zonal pricing.

3.2 NEM regional boundaries

AEMO has considered a range of options for reflecting the new physical transmission link into the dispatch model. Two network topologies have been considered for the incorporation of PEC within the NEM's dispatch model (Figure 3).

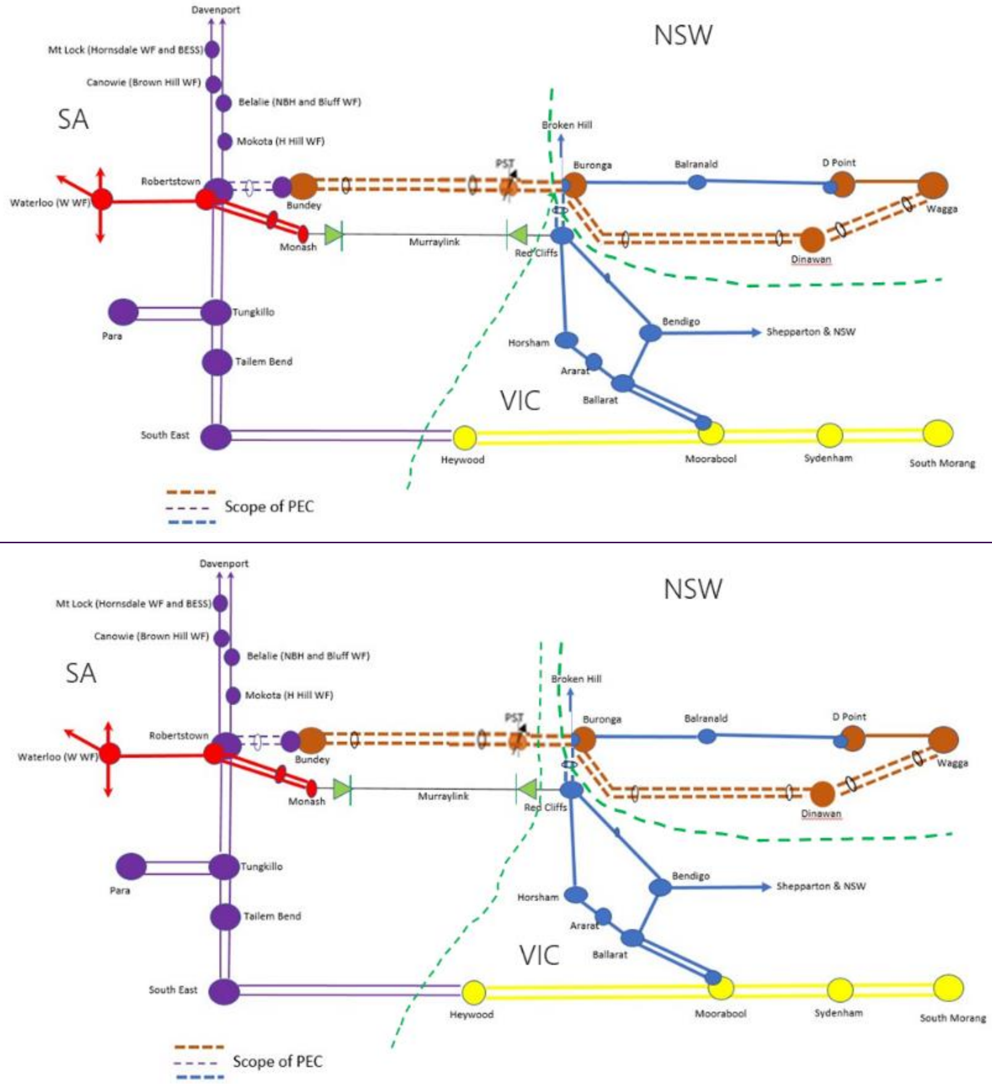
- The 'Interconnector' model, where PEC is considered as a separate line linking New South Wales and South Australia for the purposes of dispatch.
- The 'Micro-slice' model, which inserts a small Victoria region interfaced between the New South Wales and South Australia regions. This maintains the current topology of the NEM for the purposes of dispatch.

The final delivery of the full capacity of PEC will be integrated into market systems and processes as per the 'Interconnector' model. Noting that some aspects of the loop solutions discussed in this Section 3 may need to be accommodated for the delivery and energisation of phase 1.

Figure 3 Dispatch model topologies

Interconnector model

Micro-slice model



3.3 Dispatch constraints

From the perspective of dispatch, the principles of electricity market design envision a strong linkage between the physical flows relative to the flows enabled by the market dispatch engine. At a high level, the NEM is cleared on the basis of a DC network model (i.e. only active power is dispatched between nodes on the network subject to operational constraints). This construct is required to maintain a convex model from which feasible market prices can be obtained. However, at a physical level network flows occur on the physics of AC power flow. Thus, the challenge relates to developing dispatch constraints for network flows that are AC-feasible, and particularly the mesh constraint. The mesh constraint governs flows between all three regions and models sharing between the AC components of the links. In an 'Interconnector' topology model (phase 2), a mesh constraint can be developed with respect to the three links with network constraints able to be modelled separately. In an alternative 'Micro-slice' topology model, mesh equations would need to be incorporated in each network constraint.

At a high level the development of mesh constraints involves modelling AC network flows and using statistical techniques to obtain appropriate linear constraints. Two approaches considered in respect of PEC are (i) running a Multiple Linear Regression (which can be time consuming for a large AC network); and (ii) Analytical Estimation (EST) based on Network Admittance Matrix, where two different AC power flows are solved for each scenario.

The constraints are developed for a variety of system topology scenarios including a 'nil' outage case (with no network outages), a single circuit outage of PEC, a single circuit outage for the Heywood interconnector, and in addition all of the scenarios above with different phase-shifting transformer settings.

3.4 Loss model

AEMO calculates inter-regional loss equations by doing regression analysis on results of forecasted power flows of each half hour in the target year. Under the regression, the dependent variable is the ratio between marginal loss rates between regional reference nodes (RRNs), and independent variables such as regional demand and MW flow across the interconnector at the regional boundary.

For the 'Interconnector' model, AEMO will perform regression for marginal loss factor (MLF) ratios between New South Wales and South Australia Regional Reference Nodes (RRN). For the 'Micro-slice' model, AEMO will revise the existing regression processes for Victoria and South Australia and separately for Victoria and New South Wales. In addition to the PEC flow, demand in South Australia, Victoria and New South Wales will be used as independent variables in the regression.

Suitable statistical tests including R squared test will be performed to find the 'goodness of fit' of these variables. Regression fit tests will also be conducted to the existing interconnector loss equations and changes will be made if required. In addition to regional demand, additional parameters may be incorporated into the inter-regional loss equations where they are found to materially improve the 'goodness of fit', however addition of these parameters may require variations to AEMO market systems and will be considered on a case by case basis.

This will continue to be monitored and updated on an ongoing basis as part of regular constraint development and management procedures for the NEMDE.

3.5 Settlements residue and constraint management

Inter-regional settlements residue (IRSR) results from price differences between regions associated with power flows between regions across regulated interconnectors. IRSR is generally:

- Positive when electricity flows from a lower-priced region to a higher-priced region.
- Negative when electricity flows from a higher-priced region to a lower-priced region (counter-price flow).

Inter-regional price differences are generally more significant when regulated interconnectors are operating at full capacity (when the price difference reflects the cost of inter-regional transmission constraints and inter-regional transmission losses).

Eligible Registered Participants can choose to manage the risk of price separation between regions by bidding for entitlements to a proportion of the total IRSR through the settlement residue auction (SRA).

There are many variables affecting IRSR and, under some operating conditions, negative settlements residue (NSR) may occur. Under the NEM's current topology, the main causes of NSR relate to dispatch process issues and errors, and pricing and metering issues. Historically, NSR have also been driven by participant bidding behaviour at regional gateways during periods of intra-regional congestion, though this is of less relevance today[10].

The current approach to the management of NSR in the NEM is as follows:

- NER 3.6.5 requires AEMO to recover any NSR from the relevant Transmission Network Service Provider (TNSP) – which is then ultimately recovered from consumers as part of Transmission Use of Service (TUoS) charges.
- NER 3.8.10 requires AEMO to specify the management of NSR in its Constraint Formulation Guidelines.
- System Operations Operating Procedure (SOOP) 3705 specifies that if NSR is forecast, or actual NSR exceeds $100,000 (and system security can be maintained), then AEMO will apply a constraint that caps the flow of the affected interconnector (also known as 'constraint clamping')[11].

The connection of PEC is likely to result in more frequent accumulation of counter price flows (and consequently NSR) and should be considered as a normal part of constrained real time dispatch. A predominant issue for the regions connected by PEC is the occurrence of the 'spring washer' effect and implications for NSR management. This is described earlier in Section 2.

3.6 Summary

This Section 3 has described AEMO's planned approach for the market integration of PEC with regard to its staged delivery. AEMO invites stakeholder feedback on these topics or activities, or any other potential challenges, associated with the proposed changes.

	Category	Questions for consultation
1	Market integration	Do stakeholder have any questions on the planned activities associated with the market integration of PEC?

[10] This led to a subsequent rule change 'Management of negative settlement residues in the Snowy Region' with positive residues now offsetting against negative residues during the period. With the Snowy region being disbanded, this particular issue has been of less concern, though the rule remains in operation. Refer AEMC (2006), 'Management of negative settlement residues in the Snowy Region' https://www.aemc.gov.au/rule-changes/management-of-negative-settlement-residues-in-the.

[11] Refer AEMO SO_OP_3705, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/procedures/so_op_3705-dispatch.pdf?la=en.

4 Settlements residue management

The following sections seek feedback from stakeholders on specific options to manage and allocate negative settlements residue, as well as related interactions with settlements residue auctions and interactions with relevant Energy Security Board (ESB) reforms.

4.1 Adjustment of NSR procedures to accommodate PEC

As the market integration of PEC will require changes to certain operational procedures, consideration is being given to the extent to which these processes need to be adjusted NEM-wide or specifically for PEC.

There are different degrees to which operational controls and procedures could be adjusted to accommodate the management of NSR. For example, there are existing operational procedures in place to manage the extent to which NSR can accrue across interconnectors – it may be practical for these processes to remain unchanged for all non-loop interconnectors (refer Section 3.5).

With regard to PEC, as an alternate to adjusting the SRA arrangements and allocation methodology for NSR, AEMO has considered the feasibility of continuing to manage NSR through existing operational procedures and interconnector clamping. While reducing or capping NSR through constraint management can reduce the impact of negative residues, it is considered that the frequency and irregularity of NSR across PEC may be infeasible to manage in real time.

As is the case, Section 4.2 seeks stakeholder input to progress a solution for NSR management for PEC. In determining and progressing a solution, AEMO note that this may not preclude a future need to adjust these operational considerations once PEC is energised and real-word outcomes are observed.

4.2 NEM negative settlements residue management in loop flows

As described in Section 3.5, the connection of PEC is likely to result in more frequent accumulation of counter price flows (and consequently NSR) and should be considered as a normal part of constrained real time dispatch.

Approaches for the method to calculate and allocate NSR, including implications for SRA, have been explored and four options are proposed for stakeholder consideration and feedback.

4.2.1 Option 1 – Removal of NSR clamping procedure

This option would seek to eliminate the current approach of clamping the interconnector once NSRs exceed a particular threshold, impliedly allowing NSR to be considered as an acceptable dispatch outcome. This would allow NSR to accumulate more frequently given the potential for counter price flows under inter-regional congestion. This would involve a change to the operating procedure SOOP 3705.

Under this option, consideration would need to be given to how NSRs are allocated and recovered for the purposes of SRA.

- **Option 1(a): No change.** All NSRs continue to be allocated to the TNSP and recovered by AEMO on a weekly basis. If this was to be retained, no changes to the NER are required.
  - *Implications:* If NSRs were to be allocated to TNSPs uncapped, this would represent a significant increase in NSRs distributed to TSNPs who are neither able to manage nor mitigate against such risks. The subsequent recovery of these NSR from consumers is misaligned with the original design of the settlements residue framework. Further, the allocation of NSR could significantly impact upon a TNSPs ability to manage its cashflow and funding.
- **Option 1(b): All NSRs allocated to the Trader (holders of SRA units).** This would require a change to the NER.
  - *Implications:* Traders would then need to incorporate the risk and impact of NSR on their SRA cashflows into the pricing of SRA units and consequently into their risk management and liquidity processes. If NSRs perpetuate as part of regular dispatch patterns this could result in negative cashflows for Traders and nil or negative values being ascribed to the relevant flow path. There are a range of important implications relating to a change in the allocation of NSRs from TNSPs to Traders including the willingness and capability of Traders to assess the relevant risks, impacts on risk limits, SRA prudential and collateralisation requirements and potential impacts on SRA participation.
- **Option 1(c) – Shared allocation of NSRs between TNSP and Traders.** This would require a change to the NER. This could be a combination of the two approaches above, with some form of risk sharing of allocations between TNSPs and Traders.

Advantages	Disadvantages
Recognises NSR as a realistic and likely occurrence and feature of a loop flow network topology.	May need to reconsider approach allocation of residues.
The change would be limited to procedures only, or potentially the NER if options 1(b) or 1(c) were pursued.	TNSP/Traders may experience periods of negative cashflows.
Participants are able to value and price risks.	Introduce credit risk for Traders requiring SRAs to be collateralised or for AEMO to limit purchases based on Trader creditworthiness.
Responsive to market dynamics.	Re-occurring and consistent NSR may raise participant concerns or impact SRA participation.

4.2.2 Option 2 – Bundling of SRA units along pathways

Option 2 would involve the bundling of SRA units along pathways, so that proceeds to a Trader holding units along that pathway are positive. For example, a Victoria – New South Wales product could become a bundle consisting of Victoria – New South Wales, Victoria – South Australia, South Australia – New South Wales.

- The advantage of this approach is that it would avoid material system changes, though with a change to NER 3.6.5. However, it would likely limit the number of units sold at auction.
- The counter argument to this proposal is that if Traders see NSR as a risk they could themselves seek to bundle units as part of their auction purchases, and could also adjust proportions based on flow impacts, obviating the risk of AEMO making a 'point-in-time' decision to bundle proportions that do not reflect future risks.

- Bundling of units would aim to ensure there is a positive settlement outcome across the bundle of units – that is, negative and positive settlement amounts are offset within the bundle. This approach would avoid the NSR accruing to either the TNSP (Option 1a) or the Trader (Option 1b). However, the offsetting of cashflows within the bundle of units would dilute the settlement amounts that accrue on a single unit that are used by Traders to hedge inter-regional transactions.

The existing rules and procedures for the SRAs already enable bids that link any combination of unit category and quarters (also known as 'grouped bids')[12]. This provides additional flexibility for participants in portfolio construction and risk management. An additional challenge with an AEMO-led bunding of units is that bundling would represent a static decision made at a specific point, or points, in time. This would limit flexibility and adaptability to changing market conditions, whereas participants could modify portfolio positions over time especially given secondary trading of SRA units.

Advantages	Disadvantages
Limited change to NER	Non-dynamic and non-responsive to market dynamics and outcomes. AEMO makes static decision.
May potentially limit risks and impacts of negative residue	Traders cannot make dynamic bundling decisions.
	Traders now need to risk-price the bundle rather than individual lines.
	Bundling would be limited by the capacity of the smallest interconnector.

4.2.3 Option 3 – Residue reallocation for SRA

Option 3 would involve reallocating NSRs across the PEC interconnector flow paths based on an agreed metric. For example, where the net residue is positive across all three lines but is negative on a subset of lines. The reallocation would seek to ensure that all regions receive at least a zero residue. We note however that Traders could potentially do this currently post the SRA by reallocating privately based on risk requirements.

A reallocation approach could adopt a '*co-efficient*' approach, whereby the reallocation would be based on the co-efficient of the constraint equation applying to that line under system normal conditions; or a '*relative flow*' approach, whereby the reallocation would occur based on the relative flow across each transmission line in the loop. We note that a relevant consideration is whether this process applies only to flows affected by the PEC or more broadly to all other interconnectors in the NEM. At this stage, however, AEMO has assumed that this residue reallocation process only applies to interconnectors forming the loop (i.e. New South Wales – South Australia, South Australia – Victoria, Victoria – New South Wales).

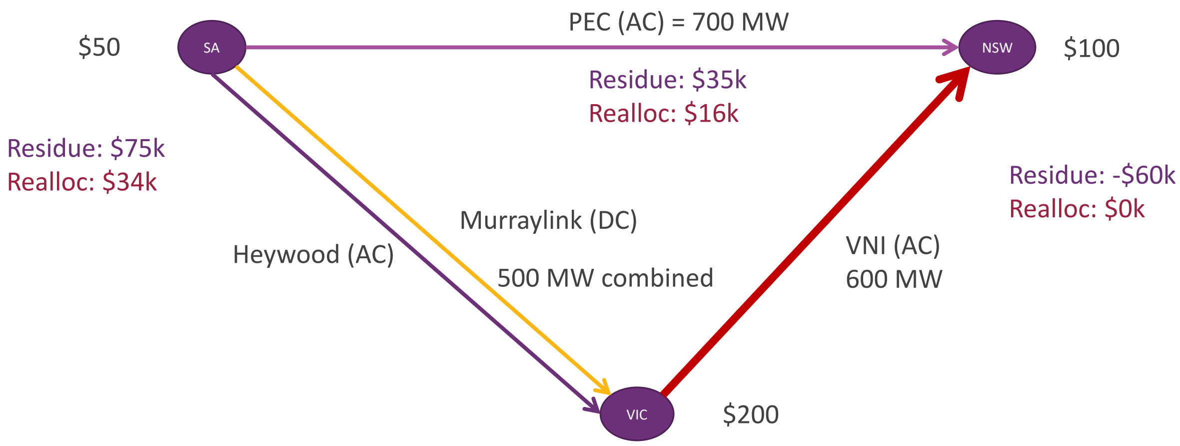
As with Option 2, the reallocation of IRSR would avoid NSR accruing to either the TNSP (Option 1a) or the Trader (Option 1b). However, the scaling of settlement amounts would dilute the cashflows that accrue on a unit that are used by Traders to hedge inter-regional transactions.

A worked example is provided below in Figure 4 where reallocations are based on the relative value of residues and where there is a total net positive residue. Appendix A2 provides further worked examples and alternative methodologies (including a relative flow approach). These examples are intended to present a range of non-exhaustive IRSR scenarios to assist in the consideration of this option.

[12] AEMO (2020) 'Settlements Residue Auction Rules', at https://aemo.com.au/-/media/files/electricity/nem/settlements_and_payments/settlements/2020/sra_settlements_residue_auction_rules_13_03_20-final.pdf?la=en.

Consideration would need to be given to how this allocation may work when total net residues are negative. This option would require a change to the SRA auction rules.

Figure 4 Example of NSR reallocation based on relative value of residue



Advantages	Disadvantages
Reallocates net positive residue, so that each line has at least zero residues.	Need to consider scenarios of potential total net negative residues, including prudential considerations.
May remove negative residue outcomes in many scenarios. Reduces value loss.	Fairness and equity of static reallocation procedure.
	Complex repricing of risk based on allocation procedure.

4.2.4 Option 4 – Financial transmission right arrangement

This option contemplates a more sophisticated approach to the development of products, trading and management of inter-regional settlement residues similar to those associated with Financial Transmission Rights (FTRs).

FTRs are a tradeable financial right associated with transmission assets. FTRs are typically implemented alongside locational marginal pricing (LMP) arrangements that are common in North America. The holders of FTRs share in the market surpluses that accrue between pricing nodes in the network.

The existing SRA arrangements in the NEM are a relatively simple method for distributing settlement residues that accrues between NEM regions. SRAs are a non-firm product with any reductions to the capacity of an interconnector resulting in a prorata decrease in the settlement that accrues to unit holders. In comparison, the implementation of FTRs is typically associated with supporting arrangements to increase the firmness of settlement outcomes for right holders.

The existing NEM rules do not incorporate SRAs within the prudential framework. Settlement risks associated with the trading of SRAs are not measured or collateralised within the prudential framework. In comparison, the implementation of FTRs is typically supported by robust prudential processes, like those employed by a clearing house, to assess and manage credit risk associated with the forward trading of FTRs.

The establishment of more sophisticated arrangements for the trading of congestion settlement residues, which could occur as part of a new congestion management framework (refer Section 4.4), would mean that it may be feasible to allocate NSR associated with loop flows to Traders (as per Option 1b).

Advantages	Disadvantages
Avoid issues associated with diluting the IRSR that would be associated with option 2 and 3.	Likely to be a relatively high cost option with a longer implementation timeline
Establishment of robust prudential arrangements would allow consideration of soluition that allocate the NSR to Traders.	May become obsolete or require significant rework if Ministers proceed with a functional change to congestion management in the NEM.

4.2.5 Guiding principles

The following guiding principles are intended to support stakeholders' considerations and assessments of SRA options presented. They will be used by the SRC in the consideration of a proposed option.

1. Effectiveness of solution – *does the solution address the problem?*
2. Timeliness of solution – *can the solution be implemented ahead of key PEC phases?*
3. Cost of solution – *is the solution cost efficient to AEMO and industry?*
4. Facilitate inter-regional trade – *will the product be useful for Traders and encourage inter-regional trade?*
5. Maintain system security – *the solution must allow AEMO to maintain system security at all times.*
6. Durability – *is the solution sustainable in during system security actions and in the presence of variable IRSR outcomes?*
7. Predictability and transparency – *does the solution support stakeholders ability to identify and manage risk and opportunity in SRA trading?*

In exploring approaches for the management of NSR across PEC, AEMO has explored options which minimise impact on existing operational and management approaches for (non-loop) interconnectors, delivering a PEC-specific approach where feasible.

4.2.6 Matters for consultation – NSR options

Stakeholder feedback is sought on the four options presented in Section 4.2 above.

	Category	Questions for consultation
2	NSR options	Which option best meets the guiding principles identified in Section 4.2.5?
3	NSR options	Are there further material advantages or disadvantages that have not been listed for any of the options outlined in this section?
4	NSR options	If NSR were to accrue to a Trader, what would be the effect of introducing prudential arrangements for Traders and how would this impact on participation in SRA?
5	NSR options	Do stakeholders have any other suggestions or alternative approaches to the management of NSR that will occur with the implementation of PEC?

4.3 Settlements Residue Auctions for PEC

The auction process for available units is staged quarterly up to 36 months prior to the trading intervals that form the basis of SRA settlement. Hence at some point during the commissioning phase of PEC, new units will become available for auction in addition to units already purchased for existing interconnection capacity. The NER is not definitive about when units shall be offered for auction during the commissioning stage noting that the Settlements Residue Committee (SRC) has previously resolved that AEMO should only offer units for auction where physical capacity has been demonstrated.

Following PEC phase 1, additional VIC – SA units may become available for auction. Any proposed change to SRA, as described in the options within Section 4.2, would be established in readiness for phase 2.

	Category	Questions for consultation
6	Principles	Should any change to NSR management is applied to loop flows only, or more broadly to all interconnector flows? While it may be possible to designate and define 'loop flow' conditions, there is a question of whether the broader principles adopted are appropriate for all flows.
7	SRA	What factors should be considered with the timing and approach of the auction of PEC SRA units?
8	SRA	What consideration needs to be given as to the treatment of units already auctioned should changes associated with PEC go ahead?

4.4 Congestion management reforms

As part of the ESB's review of transmission and access arrangements in the NEM, the ESB is considering major reforms to congestion management in the NEM, with potential consideration of more granular pricing models (including nodal pricing)[13]. At the October 2022 meeting of Energy Ministers, Ministers committed the ESB to issuing a Direction Paper on a subset of the options under consideration for stakeholder consultations, with recommendations to be considered at the first Energy Ministers' Meeting in 2023.

The ESB are developing two congestion management models[14] for consideration:

- Congestion Management Mechanism (CMM): In the event of congestion, scheduled and semi-scheduled market participants would face a congestion charge. The net effect of receiving the RRP and paying the congestion charge is that generators would effectively be settled at a locational marginal price.
- Congestion Relief Market (CRM): An ancillary services market for the provision of congestion relief in operational timeframes. The CRM would enable market participants to pay or receive additional money to adjust their dispatch up or down, based on the initial dispatch solution for a particular dispatch interval.

Both congestion management models are likely to change the way settlement residues accrues to interconnectors, and in turn, inter-regional trading in the NEM.

[13] Refer https://esb-post2025-market-design.aemc.gov.au/transmission-and-access.

[14] Further information about the CMM and CRM is available in the *Transmission Access Reform Consultation Paper May 2022* https://www.datocms-assets.com/32572/1651648061-20220501-transmission-access-reform-consultation-paper-final.pdf

While a preferred model for congestion management has not yet been determined, it would be prudent to consider the timing and interactions of any related reforms when considering changes to the SRA to support the implementation of PEC.

AEMO considers that while the ESB continues to develop the design and consult with stakeholders on congestion management reforms, there is a need to progress with a PEC-specific NSR option (including design and implementation) to ensure the required changes to market arrangements can be implemented prior to the delivery of PEC.

	Category	Questions for consultation
9	Reform	How should changes to NSR management be considered and implemented in respect of the ESB's concurrent reform activity for congestion management?

5 Next steps

This section describes the consultation approach to facilitate market readiness for both AEMO and industry ahead of PEC commissioning.

5.1 Consultation summary and approach

PEC SRA considerations and the challenge of NSR caused by the 'spring washer' effect have been discussed with the Settlements Residue Committee throughout the 2022 calendar year.

This paper seeks to explore potential options with the objective of identifying a preferred solution based on stakeholder feedback and submissions. Contingent upon stakeholders preferred solution, AEMO will then initiate the relevant process to change: the NER (NER rule change proposal); AEMO's SOP (Rules consultation process); Auction Rules (rules consultation process); or other applicable approach.

AEMO welcomes stakeholder feedback on this paper. A list of all consultation questions is provided in Appendix A3.

Written feedback can be provided by email to StakeholderRelations@aemo.com.au and is requested by 19 January 2023.

5.2 Key dates

The following key dates are being pursued:

- Submissions close on Thursday 19 January 2023
- Summary of feedback, assessment of options by the SRC and commencement of detailed implementation works Q1 2023
- Stakeholder webinar Q1 2023 to provide further information about the project and address stakeholder feedback to this paper.

A1. 'Spring washer' effect reference material

Transpower – System Operator Learning Centre. Videos – *The Spring Washer Effect Animation*. Available at: https://www.transpower.co.nz/system-operator/about-system-operation-service/learning-centre

Lu, Feiyu., 2004. *Spring Washer Effect – A Markey Clearing Engine Study of the NEMS*. Energy market Company. Available at: https://www.emcsg.com/f261,6430/Spring_Washer_Effect.pdf

Choo, C.Y., Nirmal-kumar, C.N. and Chakrabarti, B., 2006, October. Impacts of loop flow on electricity market design. In *2006 International Conference on Power System Technology* (pp. 1-8). IEEE.

Ring, B.J., 1995. Dispatch based pricing in decentralised power systems. *A thesis submitted for the degree of Doctorate of Philosophy in Management Science in the University of Canterbury*.

A2. NSR worked examples

Three worked examples of the reallocation approach of settlements residue (Option 3 in Section 4.2) are presented below for stakeholders contemplation.

A2.1 Option 3 worked examples

This 'Standard Spring Washer' worked example ('Base Case') seeks to reflect a scenario whereby the RRP spread between the three regions covers a range of $50/megawatt hour (MWh) to $200/MWh, delivering an overall net positive settlements residue for reallocation. The 'CO Method' and 'RV Method' columns compare potential reallocation outcomes for Traders under this scenario.

1. Standard Spring Washer										
	RRP									
NSW	100									
SA	50									
VIC	200									
			Base Case	**CO Method**				**RV Method**		
	Flow	Price spread (To region - From Region)	Residue	Coeff	Coeff_pr	Coeff_re	Reallocation	Flow_v	Flow_pr	Reallocation
VIC-NSW	600	-100	-60000	0.14	0.00	0.00	0	0	0.00	0
SA-VIC	500	150	75000	0.80	0.80	0.44	22222	500	0.42	20833
SA-NSW	700	50	35000	1.00	1.00	0.56	27778	700	0.58	29167
			50000		1.80			1200		

This 'Minimal Net Positive' worked example seeks to reflect a scenario whereby the RRP spread between the three regions delivers an overall minimal net positive settlements residue of $2,000 for reallocation. The 'CO Method' and 'RV Method' columns compare potential reallocation outcomes for Traders under this scenario. Of particular note is the change in allocated positive residue recorded in respect of the South Australia – Victoria and South Australia – New South Wales lines under the CO and RV method, relative to the Base Case.

2. Minimal net positives										
	RRP									
NSW	100									
SA	90									
VIC	200									
			Base Case	**CO Method**				**RV Method**		
	Flow	Price spread (To region - From Region)	Residue	Coeff	Coeff_pr	Coeff_re	Reallocation	Flow_v	Flow_pr	Reallocation
VIC-NSW	600	-100	-60000	0.14	0.00	0.00	0	0	0.00	0
SA-VIC	500	110	55000	0.80	0.80	0.44	889	500	0.42	833
SA-NSW	700	10	7000	1.00	1.00	0.56	1111	700	0.58	1167
			2000		1.80			1200		

This ‘MPC with constrained flows’ worked example seeks to reflect an extreme scenario whereby the RRP in one region (New South Wales) hits the market cap, delivering a very high positive settlements residue of $13,892,000 for reallocation. The ‘CO Method’ and ‘RV Method’ columns compare potential reallocation outcomes for Traders under this scenario. Of note is the change in allocated positive residue recorded in respect of the Victoria – New South Wales and South Australia – New South Wales lines under the CO and RV method, relative to the Base Case. Under the Base Case the allocation is relatively even between the lines, but each of the methods result in a significant redistribution to South Australia – New South Wales given the relative flows and the South Australia – New South Wales constraint coefficient.

3. MPC with constrained flows										
	RRP									
NSW	14000									
SA	90									
VIC	0									
			Base Case	**CO Method**				**RV Method**		
	Flow	Price spread (To region - From Region)	Residue	Coeff	Coeff_pr	Coeff_re	Reallocation	Flow_v	Flow_pr	Reallocation
VIC-NSW	300	14000	4200000	0.14	0.14	0.12	1,706,035	300	0.30	4,167,600
SA-VIC	500	-90	-45000	0.80	0.00	0.00	0	0	0.00	0
SA-NSW	700	13910	9737000	1.00	1.00	0.88	12,185,965	700	0.70	9,724,400
			13892000		1.14			1000		

A3. Summary of consultation questions

	Category	Questions for consultation
1	Market integration	Do stakeholder have any questions on the planned activities associated with the market integration of PEC?
2	NSR options	Which option best meets the guiding principles identified in Section 4.2.5?
3	NSR options	Are there further material advantages or disadvantages that have not been listed for any of the options outlined in this section?
4	NSR options	If NSR were to accrue to a Trader, what would be the effect of introducing prudential arrangements for Traders and how would this impact on participation in SRA?
5	NSR options	Do stakeholders have any other suggestions or alternative approaches to the management of NSR that will occur with the implementation of PEC?
6	Principles	Should any change to NSR management is applied to loop flows only, or more broadly to all interconnector flows? While it may be possible to designate and define 'loop flow' conditions, there is a question of whether the broader principles adopted are appropriate for all flows.
7	SRA	What factors should be considered with the timing and approach of the auction of PEC SRA units?
8	SRA	What consideration needs to be given as to the treatment of units already auctioned should changes associated with PEC go ahead?
9	Reform	How should changes to NSR management be considered and implemented in respect of the ESB's concurrent reform activity for congestion management?