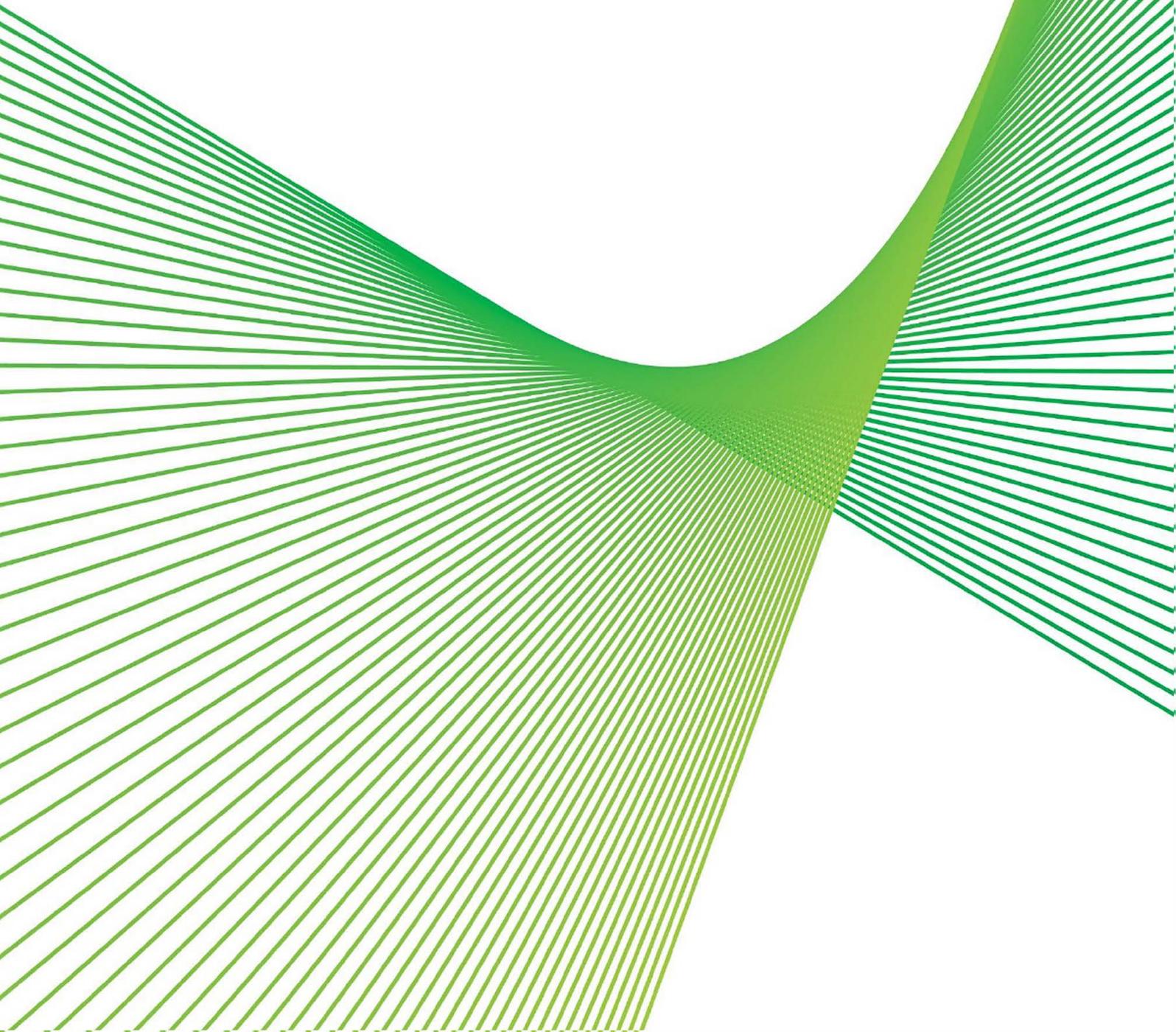# Supplementary Information 3di: Statement of Facts: Market benefits assessment and loop flows - GHD

## Covering note

*This covering note provides contextual information to assist readers to understand the purpose, scope and findings in the attached document.*

## 1. Purpose and overview

The attached report prepared by GHD addresses a query raised by the AER in relation to the modelling assumptions adopted by EY in assessing the gross market benefits that PEC will provide. The specific modelling assumption relates to the impact of loop flows, which have the potential to negatively impact the gross market benefits.

In the attached report, GHD reviewed publicly available documents to compile a statement of facts regarding the various modelling approaches and assumptions adopted in relation to the power flows on the interconnectors linking NSW, SA and VIC (i.e., PEC, Heywood and VNI). Using the information gathered, GHD assessed whether more accurate modelling of the loop flow involving those interconnectors would have materially affected EY's estimated market benefits for PEC. As explained below and in the attached report, GHD found that the impact of loop flows is not expected to have a material impact and EY's modelling assumptions are reasonable. The report is technical in nature and is provided to address the issues raised by the AER.

## 2. Scope

Various documents were reviewed including: AEMO implementation paper identifying the need for a loop flow constraint in NEMDE once PEC stage 2 is in service; market modelling completed by ACIL Allen to assist AEMO in assessing the need for a loop flow constraint; PEC benefits assessments undertaken by ElectraNet for the RIT-T; AEMO's modelling for the 2024 ISP; and EY's modelling for their 2024/2025 assessment of the gross market benefits delivered by PEC. Power flow analysis was also undertaken to verify whether the combination of interconnection flows extracted from the EY market modelling results could be achieved by adjusting the phase shift transformers (**PST**) taps at Buronga.

## 3. Key Findings

While the modelling undertaken by ElectraNet for the RIT-T did not consider the loop flow when assessing capacity expansion decisions, there is a low risk that caused a material error because:

- The rigorous review of the modelling approach by various independent parties did not identify any concerns with the capacity expansion that underpinned the market benefit assessment.

- The capacity expansion planning adopted conservative limits for the additional capability provided by PEC.

The modelling undertaken for the 2024 ISP did not model loop flows in either the capacity planning run or the time sequential runs. This risks over estimating benefits but only if the power flows on PEC, Heywood and VNI in the market modelling runs cannot be achieved in the AC power flow utilising the full range of the PST.

In the case of the EY market modelling, verification studies performed for the 2027/28 year (first year with PEC Stage 2 in service) demonstrate that by appropriate adjustment of the PST taps, the interconnector power flows (PEC, VNI, Heywood and Murraylink) in the market modelling results for most dispatch intervals (96.1%) could be achieved in the actual power system. For 3.9% of intervals the interconnector flows in the market modelling results exceed those that can be achieved by adjusting the PST taps in the AC power flow.

The relatively small number of dispatch intervals that have interconnector flows that exceed those that can be achieved by adjusting the PST taps, suggests that it is unlikely that the market benefits have been materially overestimated.

The loop flow constraint used in the modelling undertaken by ACIL Allen reflects static assumptions regarding the setting of the PST taps. Using that constraint equation in market modelling undertaken to assess the market benefits delivered by PEC is likely to underestimate benefits due to inadequacies in the ability of the static loop flow equations to reflect the full range of interconnector powers available through adjustment of the PST taps.

## 4. Conclusion

The modelling approach adopted by EY, which is consistent with the RIT-T undertaken by ElectraNet and AEMO's 2024 ISP, is reasonable and unlikely to have materially overestimated the market benefits provided by PEC.

# Project Energy Connect

## Statement of Facts: market benefits assessment and loop flows

Transgrid

8 February 2026

| Project name | PEC statement of facts – market benefits assessment and loop flows | | | | | | |
|---|---|---|---|---|---|---|---|
| Document title | Project Energy Connect \| Statement of Facts: market benefits assessment and loop flows | | | | | | |
| Project number | 12657533 | | | | | | |
| File name | Document5 | | | | | | |

| Status Code | Revision | Author | Reviewer | | Approved for issue | | |
|---|---|---|---|---|---|---|---|
| | | | Name | Signature | Name | Signature | Date |
| S3 | 1.0 | ■■■■ | ■■■■ | | ■■■■ | | 28/11/2024 |
| S3 | 1.1 | ■■■■ | ■■■■ | | ■■■■ | ■■■■ | 31/1/2025 |
| S4 | 1.2 | ■■■■ | ■■■■ | | ■■■■ | ■■■■ | 8/2/2026 |

**GHD Pty Ltd | ABN 39 008 488 373**

Contact: ■■■■■■■■, BGL Power Advisory | GHD
Level 9, 145 Ann Sreet
Brisbane, Queensland 4000, Australia
**T** ■■■■■■■ | **F** ■■■■■■■ | **E** ■■■■■■■■ | **ghd.com**

→ **The Power of Commitment**

# Executive summary

GHD has reviewed public domain information to compile a statement of facts that documents the various sets of market modelling that have assessed the market benefits delivered by Project EnergyConnect (PEC). The summary compiled has paid careful attention to the approach taken in the market modelling to consider the relationship between power flows on the interconnectors linking NSW, SA and VIC (i.e. PEC, Heywood and VNI). The information gathered has been used to assess whether more accurate modelling of the loop flow involving those interconnectors would have materially altered the calculated market benefits.

The review supports the following key findings and recommendations.

1. The review of the modelling undertaken to assess the market benefits of PEC suggests that the modelling approach adopted in the ISP, by ElectraNet for the RIT-T assessment and that proposed by EY are unlikely to have materially overestimated the market benefits provided by PEC.

   In the case of the EY market modelling, additional verification studies have been performed by GHD for the 2027/28 year. Those studies demonstrate that by appropriate adjustment of the Phase Shift Transformer (PST) taps the interconnector power flows (across PEC, VNI, Heywood and Murraylink) in the market modelling results for most dispatch intervals (96.1%) could be achieved in AC power flow studies modelling the physical power system with PEC in service. For 3.9% of intervals the interconnector power flows in the market modelling results exceed those that can be achieved by adjusting the PST taps in the AC power flow.

   The small number of dispatch intervals that have interconnector power flows that exceed those that can be achieved by adjusting the PST taps, suggests that it is unlikely that the market benefits may have been materially overestimated.

2. The modelling approach adopted by ACIL Allen is likely to underestimate benefits due to inadequacies in the ability of the loop flow equation developed by AEMO to represent the capability of PEC.

3. It is recommended that Transgrid work closely with AEMO to ensure the loop flow constraint implemented in NEMDE and pre-dispatch accurately reflects the capability of PEC.

4. It is recommended that Transgrid work with AEMO to develop appropriate operating advice guiding how the PST taps should be adjusted to optimise power flows and how that approach should be reflected in dispatch and pre-dispatch versions of the loop flow constraint.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the Report.

# Contents

# Table index

# Figure index

# Appendices

**No table of contents entries found.**

# Attachments

**No table of contents entries found.**

# 1.     Introduction

## 1.1     Purpose of this report

GHD has reviewed public domain information to compile a statement of facts that documents the various sets of market modelling that have assessed the market benefits delivered by Project EnergyConnect (PEC). The summary compiled has paid careful attention to the approach taken in the market modelling to consider the relationship between power flows on the interconnectors linking NSW, SA and VIC (i.e. PEC, Heywood and VNI). The information gathered has been used to assess whether more accurate modelling of the loop flow involving those interconnectors would have materially altered the calculated market benefits.

## 1.2     Scope and limitations

*This report: has been prepared by GHD for Transgrid and may only be used and relied on by Transgrid for the purpose agreed between GHD and Transgrid as set out in section 1.1 of this report.*

*GHD otherwise disclaims responsibility to any person other than Transgrid arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

*The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.*

*The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.*

*The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.*

**Accessibility of documents**

*If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.*

## 1.3     Assumptions

We have assumed that the information in the referenced documents is accurate, GHD has not sought to independently verify the accuracy of that information.

# 2. Statement of facts

The market benefits of Project EnergyConnect (PEC) have been assessed several times across the life of the project as summarised in Table 3. There have been three different approaches used to ensure that the power flows on the interconnectors linking NSW, SA and VIC (i.e. PEC, Heywood and VNI) reflect the power flows expected in the actual power system considering the ability to control the power flow on PEC provided by the Phase Shifting Transformers (PSTs) at Buronga.

The table notes the different approaches used to model an appropriate relationship between power flows on the HVAC interconnectors connecting NSW, SA and Vic. The loop flow issue is described in the PEC Integration Paper published by AEMO in May 2023[1] and refers to the need to ensure that the power flows in the interconnectors in the NEM Dispatch Engine (NEMDE) reflect the relationship that will be observed on the actual power system. One approach for achieving this is to implement a loop flow constraint in NEMDE. That approach can lead to the spring-washer effect illustrated in Figure 1 when one of the interconnectors is constrained by a network limit.
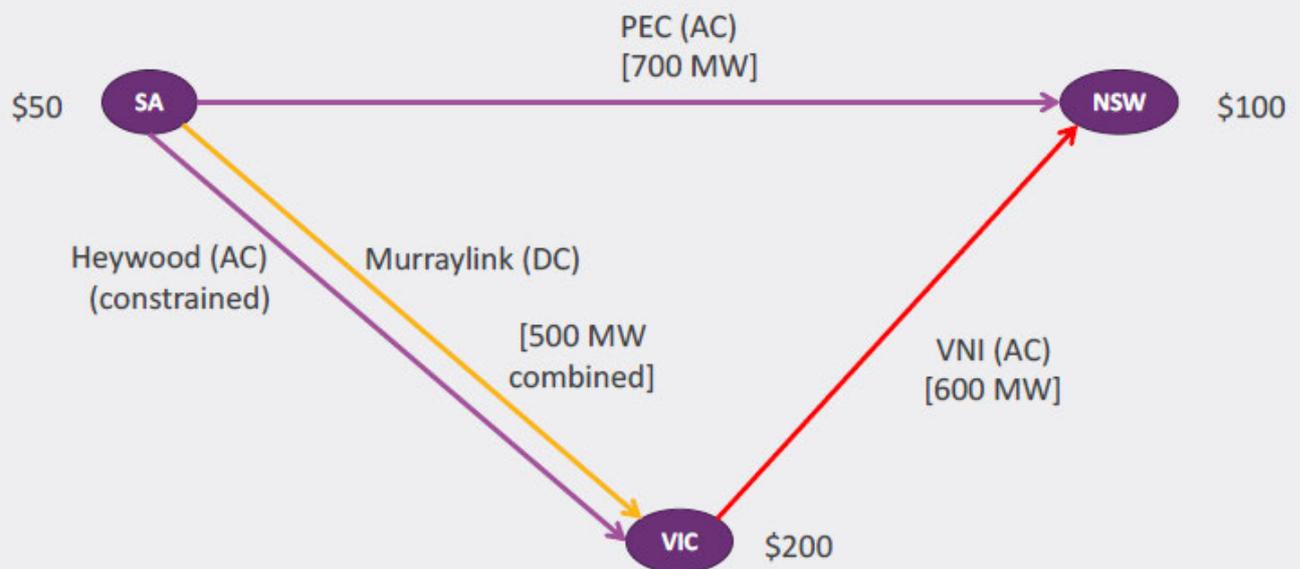


*Figure 1        Illustration of the loop flow created by PEC and the potential spring washer effect [2]*

The approaches for managing the loop flow adopted in the market modelling listed in Table 3 varies between the following the options:

---

[1] **pec-implementation--update-on-market-integration-may.pdf**
[2] **pec-market-integration-paper.pdf**

- Assume that the PST provided sufficient range so that the flow on PEC is independent of the other interconnectors and no explicit modelling of loop flow is needed. This is adopted in the ESOO, ISP, by FTI in the modelling performed in support of the CPA and in the EY modelling.
- Explicitly model the loop flow via a constraint in the market model. This approach is proposed in the PEC implementation paper developed by AEMO and in the market modelling undertaken by ACIL Allen.
- Explicitly modelling the loop flow via a dc load flow within the optimisation engine in the market model. This approach was adopted by ElectraNet in the RIT-T market modelling.

Section 5, presents findings regarding the different approaches utilised and whether they are likely to over or underestimate the market benefits delivered by PEC.

# 3. Impact of loop flows on market benefits

The main sets of market modelling referred to in Table 3 are discussed in the following sections and conclusions drawn regarding whether the approach taken to modelling the loop flows is likely to underestimate or overestimate the market benefits delivered by PEC.

## 3.1 RIT-T modelling performed by ElectraNet

The modelling undertaken by ElectraNet for the RIT-T did not consider the loop flow when using the LT modelling run to assess new entry decisions. As such the benefit provided by PEC may have been exaggerated. The risk of this causing a material error is however expected to be low for the following reasons:

- there was a rigorous review of the modelling approach for various independent parties and GHD expects that those reviews would have identified any situations where the modelling was presenting unrealistic impacts of PEC on the modelled capacity expansion.
- we expect that the LT model would have adopted conservative limits for the additional capability provided by PEC.

Other aspects of the market benefits delivered by PEC would have been derived from the ST (time sequential) run. That run modelled the loop flow via a DC load flow and should have provided an accurate assessment of the impact of the loop flow on the market benefits derived from differences in the time sequential runs with and without PEC. We note that the network technical assumptions report accompanying the PACR stated the range of the PST at Buronga was 30 degrees phase shift angle, which is less range than actually provided by the delivered transformer[3]. If the ST run modelled the 30 degree range that may have underestimated the market benefits derived from that modelling.

On balance it is unlikely that a more accurate inclusion of loop flows within the RIT-T market modelling would have materially changed the calculated market benefits.

## 3.2 Modelling using the loop flow constraint proposed by AEMO

The modelling undertaken by ACIL Allen for AEMO using the loop flow constraints proposed by AEMO is likely to significantly underestimate the market benefits delivered by PEC. The key reasons for this finding are:

- The loop flow constraint only models utilising of 20% of the range of the PST and therefore does not model the full capability of PEC.
- The loop flow constraints developed by AEMO assumed network conditions expected at the time stage 2 of PEC is commissioned and would not be an accurate representation of the loop flows once further actionable projects such as VNI West are delivered.

---

[3] SA Energy Transformation RIT-T, Network Technical Assumptions Report, ElectraNet, 13 February 2019

## 3.3 Modelling proposed by EY

The modelling proposed by EY has the potential to provide an optimistic view of the market benefits delivered by PEC. This is because the modelling assumes that flow on PEC is independent of power flows on the other interconnectors.

To test whether this is likely to be a material overestimation GHD has undertaken AC power flow studies to verify whether the interconnector flows reported in the EY market model for the financial year ending 30 June 2028 can be achieved with the designed PST. Our assessment confirms that for most dispatch intervals (96.1%) the interconnector power flows in the market modelling results could be achieved by adjusting the PST in AC power flow studies.

The small number of dispatch intervals that have interconnector flows that exceed those that can be achieved by adjusting the PST taps, suggests that it is unlikely that the market benefits may have been materially overestimated. Further details of our assessment are provided in Section 4.

## 3.4 Modelling in the ISP

The modelling undertaken for the ISP does not model loop flows in either the capacity planning run or the time sequential runs. This risks over estimating benefits but only if the power flows on PEC, Heywood and VNI in the market modelling runs can't be achieved in the AC power flow utilising the full range of the PST.

# 4. Verification of interconnector flows in the EY market modelling

AEMO has develop a set of three loop flow equations which ACIL Allen used in their market modelling studies to illustrate the potential for negative residues accruing across interconnectors once PEC is fully operational. The loop flow equation set developed by AEMO consists of three equations with each equation assuming a different setting for the PST tap as shown in Figure 2. The loop flow constraint set is insufficient to describe the full capability of PEC as it does not consider the full range of the PST. Implementing that constrain set in NEMDE or a market model is therefore likely to be overly restrictive on the power flows allowed across PEC, which risks significantly underestimating market benefits.

To avoid this, the approach proposed by EY of modelling PEC as an independently controllable interconnector is reasonable. However, the interconnector flow results obtained from the EY market modelling should be validated via power flow studies to confirm that it is feasible that those power flows can be achieved by adjusting the PST taps.

Proposed PEC loop model equality constraint:

$PEC = x_{VNI} * VNI + x_{Heywood} * Heywood + \Theta_{PST}$

Where PEC, VNI and Heywood are southward flows i.e.:
- x### represents the coefficient
- PEC represents NSW to SA,VNI represents NSW to VIC, Heywood represents VIC to SA
- The $\Theta$ PST represents positive flows from SA to NSW

Coefficients and $\Theta$ PST are set out below:

| Scenario | Coefficients – Analytical Estimation | | |
|---|---|---|---|
| | xVNI | xHeywood | $\theta$PST |
| 1) No outage, PST -6.73° | 0.1413 | 0.8084 | -20.9260 |
| 2) No outage, PST 0° | 0.1410 | 0.8073 | 73.7164 |
| 3) No outage, PST 8° | 0.1408 | 0.8090 | 186.6568 |

The PSTs will be integrated into dispatch on the loop flow constraint via an offset coefficient. AEMO does not expect to use dispatch for PST setpoint control. The PST setting that best reflects the position of the PST angle on the transformer during pre-dispatch will be an input into NEMDE via the loop flow constraint equation.

*Figure 2      loop flow equation set developed by AEMO[4]*

# 4.1    Verification method

The following approach was applied by GHD as a means of validating the assumption of the independent control of PEC that has been built into the EY market modelling:

1. EY provided results from their market modelling including regional load, generation and interconnector flows for each one-hour dispatch interval.

2. GHD considered the market modelling results for the first full year of PEC operation (2027/28). The 2027/28 year was analysed as it is likely to be prior to VNI West being in service and thereby avoids any additional complications in the loop flows between NSW, VIC and SA.

3. GHD analysed the market modelling results to identify 10 dispatch intervals with the greatest separation between the power flows in the market model and those predicted using the loop flow equations developed by AEMO. As those intervals all had relatively consistent interconnector transfers, we also extracted three other dispatch conditions to provide a more complete consideration of the range of power transfers expected across the PEC and Heywood interconnectors.

4. The periods of interest were identified via the following analysis of the market modelling results:

   a. Using the loop flow equations defined by AEMO and the market modelling results for the interconnector power flows, we calculated the PEC power flow predicted by the three loop flow equations for each dispatch interval. (i.e. $PEC_1$, $PEC_2$ and $PEC_3$ were calculated using the form of the loop flow equation assuming PST tap of -6.73 degrees, 0 degrees and 8 degrees respectively).

   b. Using the PEC power flow from the market model for each dispatch interval (i.e. $PEC_{mm}$), we identified the version of the loop flow equation that provided the closest alignment between the PEC power flow in the market model and that calculated using the loop flow equations. The difference between the PEC power flow in the market model and that allowed by the loop flow equation set was calculated applying the following formula: Min (ABS($PEC_{mm}$ - $PEC_1$), ABS($PEC_{mm}$ – $PEC_2$), ABS($PEC_{mm}$ – $PEC_3$)).

   c. We sorted all dispatch intervals in the year to identify the 10 intervals with the greatest separation between the PEC power flow in the market model and that calculated using the loop flow equations.

   d. As each of those intervals had fairly similar flows across PEC (approximately 800 MW leaving SA) and Heywood (approximately 650 MW leaving SA), three extra dispatch intervals were selected. Those addition dispatch intervals had high differences between the power flow across PEC in the market

[4] **pec-market-integration---directions-paper-for-consultation.pdf**

modelling results and that predicted by the AEMO loop flow equations and spanned the range of flows across PEC and Heywood:

    i.    Additional interval 1 has PEC importing 800MW into SA with 433 MW flowing into SA across Heywood

    ii.    Additional interval 2 has PEC exporting 800MW from SA with 650 MW flowing into SA across Heywood

    iii.    Additional interval 3 has PEC importing 768MW into SA with 650 MW flowing into Victoria across Heywood

5.    For each period of interest an AC power flow study was performed with the regional load and generation scaled to match that in the market modelling results and the PST taps adjusted to see if the interconnector flows in the market modelling results could be achieved while not exceeding the PST tap range.

## 4.2    Verification results

Table 1 shows the 13 dispatch intervals used in the verification power flow studies.

*Table 1    Dispatch intervals tests via AC power flow studies*

| Period Start | Regional demand | | | | | Regional generation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | QLD | SA | TAS | VIC | NSW | QLD | SA | TAS | VIC | NSW |
| 7/02/2028 11:00 | 4985 | 313 | 1053 | 4186 | 6883 | 5376 | 1997 | 894 | 4672 | 5051 |
| 7/02/2028 12:00 | 4839 | 174 | 992 | 4143 | 7593 | 5231 | 1863 | 833 | 4633 | 5777 |
| 7/02/2028 13:00 | 5019 | 190 | 985 | 4221 | 8282 | 5411 | 1878 | 855 | 4683 | 6532 |
| 7/02/2028 14:00 | 5199 | 333 | 1020 | 4598 | 9127 | 5590 | 2016 | 1019 | 4926 | 7381 |
| 8/01/2028 12:00 | 3654 | 90 | 1002 | 3282 | 8045 | 3654 | 1876 | 770 | 3801 | 6745 |
| 7/02/2028 10:00 | 5155 | 621 | 1084 | 4253 | 6804 | 5546 | 2291 | 925 | 4742 | 4974 |
| 7/02/2028 15:00 | 5932 | 593 | 1070 | 4745 | 10327 | 6373 | 2261 | 1070 | 5065 | 8465 |
| 7/02/2028 16:00 | 7088 | 959 | 1154 | 4882 | 11337 | 7129 | 2552 | 1154 | 5239 | 9875 |
| 16/07/2027 0:00 | 6173 | 2132 | 1320 | 5972 | 9556 | 6631 | 909 | 1948 | 6165 | 9853 |
| 21/02/2028 10:00 | 4487 | 676 | 1015 | 4863 | 5668 | 4740 | 2403 | 1446 | 4704 | 4103 |
| 21/02/2028 11:00 | 3959 | 348 | 974 | 4201 | 5730 | 4006 | 2078 | 864 | 4584 | 4388 |
| 8/07/2027 21:00 | 7114 | 2256 | 1390 | 6121 | 9641 | 6338 | 2478 | 1591 | 7640 | 8937 |
| 12/03/2028 9:00 | 3776 | 894 | 1137 | 3374 | 4699 | 4216 | 1076 | 818 | 2489 | 5605 |

AC power flow studies for each of the 13 dispatch intervals were undertaken and the PST tap settings adjusted to provide the closest possible match to the market modelling results. The results are summarised in Table 2 which shows:

–     the interconnector flows in the market modelling results.

–     the interconnector flows achieved in the AC power flow studies, and

–     the phase angle setting required on the PST.

The results show that for all but two of the dispatch intervals, a close match between the interconnector flows in the AC power flow and those in the market modelling results was able to be achieved by adjusting the settings on the PST.

The last two rows in dispatch intervals Table 2 show interconnector transfers in the market modelling results that could not be achieved even with the PST at the extreme of its tap range. These dispatch intervals have PEC and Heywood transferring power in opposite directions at close to the ratings of the individual interconnectors.

**Table 2**     *Verification study results*

| Period Start | Interconnector power flows from market modelling results | | | | Interconnector power flows from ac power flow studies | | | | PST phase angle |
|---|---|---|---|---|---|---|---|---|---|
| | VNI | Heywood | Murraylink | PEC | VNI | Heywood | Murraylink | PEC | degrees |
| 7/02/2028 11:00 | 1000 | -650 | -127 | -800 | 995 | -643 | -127 | -787 | 20 |
| 7/02/2028 12:00 | 1000 | -650 | -127 | -800 | 1003 | -647 | -127 | -789 | 20 |
| 7/02/2028 13:00 | 1000 | -650 | -127 | -800 | 1002 | -647 | -127 | -787 | 20 |
| 7/02/2028 14:00 | 1000 | -650 | -126 | -800 | 985 | -644 | -126 | -784 | 20 |
| 8/01/2028 12:00 | 1000 | -650 | -200 | -800 | 1037 | -641 | -200 | -798 | 17.5 |
| 7/02/2028 10:00 | 1000 | -650 | -121 | -800 | 981 | -634 | -121 | -784 | 20 |
| 7/02/2028 15:00 | 1000 | -650 | -121 | -800 | 964 | -650 | -121 | -779 | 20 |
| 7/02/2028 16:00 | 1000 | -650 | -69 | -800 | 948 | -656 | -69 | -752 | 22.5 |
| 16/07/2027 0:00 | 168 | 433 | 73 | 800 | 117 | 402 | 73 | 827 | -2.5 |
| 21/02/2028 10:00 | 1000 | -650 | -200 | -759 | 973 | -657 | -200 | -723 | 20 |
| 21/02/2028 11:00 | 1000 | -650 | -199 | -758 | 1015 | -658 | -199 | -737 | 20 |
| 8/07/2027 21:00 | 1000 | 650 | -14 | -800 | 1031 | 471.4 | -14 | -581.2 | -40 |
| 12/03/2028 9:00 | -400 | -650 | -200 | 768.6 | -498 | -582.6 | -200 | 730 | 40 |

The 2027/28 market modelling results were analysed to identify the number of dispatch intervals where interconnector flows exceed the flows that could be achieved in the AC power flow. That analysis showed that in 2027/28:

– there were 337 intervals where flow on Heywood was greater than 471.4MW into SA and the flow on PEC was greater than 581.2MW into NSW. This represents 3.86% of the intervals in the year.

– there were 4 intervals where flow on Heywood was greater than 582.6MW into Victoria and the flow on PEC was greater than 730MW into SA. This represents 0.05% of the intervals in the year.

– In total that 3.9% of the one our intervals have interconnector power flows that exceeded those that could be achieved by adjusting the PST taps in the AC power flow.

The results in Table 2 cover the full range of power flows across Heywood and PEC in the market modelling results for 2027/2028. The results demonstrate that for most dispatch intervals (96.1%) the interconnector flows in the EY market modelling results can be obtained by adjusting the PST taps. For 3.9% of intervals the interconnector flows exceed those that can be achieved by adjusting the PST taps.

The small number of dispatch intervals that have interconnector flows that exceed those that can be achieved by adjusting the PST taps, suggests that it is unlikely that the market benefits may have been materially overestimated.

# 5.    Findings and Recommendations

1.  The review of the modelling undertaken to assess the market benefits of PEC suggests that the modelling approach adopted in the ISP, by ElectraNet for the RIT-T assessment and that proposed by EY are unlikely to have materially overestimated the market benefits provided by PEC.

    In the case of the EY market modelling, additional verification studies have been performed by GHD for the 2027/28 year. Those studies demonstrate that by appropriate adjustment of the PST taps the interconnector power flows in the market modelling results for most dispatch intervals (96.1%) could be achieved in AC power flow studies modelling the physical power system with PEC in service. For 3.9% of intervals the interconnector power flows in the market modelling results exceed those that can be achieved by adjusting the PST taps in the AC power flow.

    The small number of dispatch intervals that have interconnector power flows that exceed those that can be achieved by adjusting the PST taps, suggests that it is unlikely that the market benefits may have been materially overestimated.

2.  It is recommended that Transgrid work closely with AEMO to ensure the loop flow constraint implemented in NEMDE and pre-dispatch accurately reflects the capability of PEC.

3.  It is recommended that Transgrid work with AEMO to develop appropriate operating advice guiding how the PST taps should be adjusted to optimise power flows and how that approach should be reflected in dispatch and pre-dispatch versions of the loop flow constraint.

**Table 3 Project EnergyConnect – Market Benefits Assessment**

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|---|---|---|---|---|
| Nov 2016 | ElectraNet | PSCR[5] | Did not assess benefits | Noted the potential benefits of controllability of power flows will be considered in PADR |
| Jun 2018 | ElectraNet | PADR[6] | Net market benefits of around $1bn over 21 years.<br><br>Cost of interconnector estimated as $1.5bn<br><br>Costs and benefits in AUD as at June 2018 | Market Modelling undertaken in Plexos:<br>– LT and ST model runs adopted different interconnector limits and constraints.[7] LT model used to determine entry of new generation and transmission capacity. It represented each region as a single node. Regions are connected by notional interconnectors with no loop flow constraint.<br>– ST model used a full network representation of the mainland regions and included the full network representation of all transmission reactance, impedance and ratings. GHD assumes this utilised the DC load flow option in Plexos. It is unclear how the phase shift transformer (PST) is represented in the Plexos ST model. The network technical assumptions published with the PADR listed the PST as having a 30-degree phase shift.<br><br>TransGrid stated that market modelling must be capable of accurately representing a loop structure between NEM regions.[8]<br><br>AEMO has explicitly considered the issue of loop flows as part of its 2016 NTNDP[9], and ElectraNet and AEMO have also discussed this issue as part of the RIT-T assessment.<br><br>The 2016 NTNDP assessed the proposed Riverlink interconnection between Buronga and Robertstown and noted the potential issues associated with loop flows. The NTNDP did not model a loop flow constraint. It avoided that by instead modelling a change to region boundaries such that Victoria -NSW boundary ran through Buronga. Riverlink then became and augmentation that increased the transfer capability between Victoria and NSW and between Vic and SA without establishing a NSW to SA interconnection[10]<br><br>Independent review of network model for LT and ST run by Oakley Greenwood found that the approach is reasonable[11] |
| Feb 2019 | ElectraNet | PACR[12] | Net market benefits of around $900m over 21 years. | Market modelling undertaken in Plexos: |

---

[5] RIT-T was titled SA Energy Transformation
[6] SA Energy Transformation RIT-T, Project Assessment Draft Report, ElectraNet, 29 June 2018 available at **Reports & Publications | ElectraNet**
[7] SA Energy Transformation RIT-T, Market Modelling Report, ElectraNet, 29 Jube 2018
[8] TransGrid, *Submission in relation to South Australian Electricity Transformation RIT-T PSCR,* 27 February 2017, p 6.
[9] AEMO, National Transmission Network Development Plan 2016, p. 88.
[10] **2016-national-transmission-network-development-plan.pdf**
[11] Oakley Greenwood reviews were completed for the PADR and PACR
[12] SA Energy Transformation RIT-T, Project Assessment Conclusions Report, ElectraNet, 13 February 2019 available at **Reports & Publications | ElectraNet**

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|------|--------|---------|---------------------------|------------------------------|
| | | | Cost of interconnector estimated as $1.53bn<br><br>Costs and benefits in AUD as at Feb 2019 | – Market Modelling report clarifies network representation in LT and ST model[13]. LT representation has minimal representation of interconnector limits and intra-regional limitations. The time sequential model uses the full network representation with all important constraints modelled.<br>– No material change from the PADR approach with respect to loop flows.<br>Independent review by Oakley Greenwood found that the modelling methodology is sound[14].<br>It is unclear from the published reports how the PST was modelled in the DC load flow and importantly what range was assumed and what objective function was assumed to choose the tap setting for the PST in each dispatch interval in the ST. it likely that the market benefits assessed were conservative as the transmission if the DC load flow in the ST run did not represent the +/- 40 degree range of the PST that is provided on the procured transformers |
| Mar 2019 | AER | RIT-T dispute | No reassessment of market benefits | Dispute raised by SACOSS that RIT-T did not adequately consider reliability risks associated with generator closure. AER. AER determined that there was no requirement to amend the RIT-T.<br>No specific mention of loop flows |
| Jan 2020 | AER | Determine project satisfies RIT-T | Did not undertake any market modelling. Used Frontier Economics to review modelling undertaken by ElectraNet.<br>The AER estimated gross benefits valued at $1.2- $1.3 billion in its Determination.[15]<br>Assessed net market benefits in central scenario may be $269m | Focus was a review of the application of the RIT-T by ElectraNet and not independently calculating market benefits.<br>The AER asked ElectraNet for revised modelling including testing of an AER sensitivity that revealed low net market benefits of $270m.<br>Frontier Economics did not identify any concerns with the modelling approach undertaken by ElectraNet.<br>The AER determined that the project satisfied the RIT-T. |
| Sep 2020 | ElectraNet | Material change of circumstance | Cost increase from $1.53bn to $2.43bn, gross benefits increased from $1.25bn to $1.86bn.<br>Net benefit = $148m | Following publication of the 2020 ISP input assumptions ElectraNet completed an update of the cost benefit assessment to consider whether there had been a material change in circumstances based on the latest information.<br>Updated CBA aligned with assumptions in 2020 ISP |
| May 2021 | AER[16] | CPA determination | $2.28bn capex | FTI Consulting ("FTI") engaged by Transgrid to undertake independent analysis of the expected gross benefits of EnergyConnect. Assessed net benefit as 1.6bn[18]: |

---

[13] SA Energy Transformation RIT-T, Market Modelling Report, ElectraNet, 29 Jube 2018
[14] Oakley Greenwood reviews were completed for the PADR and PACR
[15] **AER RIT-T Decision**
[16] **TransGrid and ElectraNet – Project EnergyConnect contingent project | Australian Energy Regulator (AER)**
[18] **TransGrid - A.11B - FTI Consulting, Benefits of Project EnergyConnect - June 2020.pdf**

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|---|---|---|---|---|
| | | | AER did not independently assess market benefits by relied on updated assessments by ElectraNet using AEMO ISP inputs.<br><br>The AER estimated gross benefits valued at $1.2- $1.3 billion in its Determination.[17] | – Four categories of benefits from EnergyConnect have been estimated, each aligned with the RIT-methodology: avoided variable costs, avoided fixed costs, avoided Renewable Energy Zone transmission costs, and new-build generator capital costs.<br><br>– The analysis uses FTI's in-house power market model, running on Plexos, to simulate the NEM from 2020 to 2040, based on AEMO's Draft ISP 2020 central scenario assumptions. The counterfactual scenario models the NEM without EnergyConnect, including current topology, existing interconnectors, and committed investments (e.g., VNI and QNI upgrades). EnergyConnect's impact is assessed by comparing this baseline to a scenario where EnergyConnect is operational from July 2023.<br><br>– As it is based on the ISP it is unlikely that the model included any loop flow constraint or DC load flow to model the AC interconnection power flow relationships. |
| Nov 2022 | AEMO | PEC Integration | AEMO Implementation paper[19] identified the need for a loop flow constraint in NEMDE | Need for loop flow constraint is described in the implementation paper, but no loop flow equations was provided.<br><br>The report summarised international experience with loop flows including in New Zealand, USA and Europe and flagged the need to consider appropriate measures to manage negative residues. |
| May 2023 | AEMO | PEC integration | AEMO update to the implementation paper providing loop flow constraint[20] | The updated implementation paper provided a loop flow constraint:<br><br>– The constraint equation was developed through statistical analysis of power flows obtained through AC power flow analysis. The aim was to obtain an approximate linear relationship for the flows on the three interconnectors for different settings on the PST. |

---

[17] __AER Decision__
[19] __pec-market-integration-paper.pdf__
[20] __pec-implementation--update-on-market-integration-may.pdf__

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|---|---|---|---|---|
| | | | | Proposed PEC loop model equality constraint:<br><br>$PEC = x_{VNI} * VNI + x_{Heywood} * Heywood + \Theta_{PST}$<br><br>where PEC, VNI and Heywood are southward flows i.e:<br><br>• x### represents the coefficient<br>• PEC represents NSW to SA<br>• VNI represents NSW to VIC<br>• Heywood represents VIC to SA<br>• The Θ PST represents positive flow from SA to NSW<br><br>Coefficients and θPST are set out below:<br><br>_(table)_<br>**Scenario** / **Coefficients - Analytical Estimation** (xVNI, xHeywood, θPST)<br>1) No outage, PST -6.73° : 0.1413 / 0.8084 / -20.9260<br>2) No outage, PST 0° : 0.1410 / 0.8073 / 73.7164<br>3) No outage, PST 8° : 0.1408 / 0.8090 / 186.6568<br><br>The following applies (noting **positive flow is to SA**)<br><br>• PEC is close to binding to SA, the Θ PST should be **negative**, because this reduces the flow on PEC to SA.<br>• PEC is close to binding to NSW, the Θ PST should be **positive**, because this **increases** the flow on PEC to SA.<br><br>In summary, the PST seems to act to increase or decrease flow on PEC, allowing NEMDE to then change the dispatch more optimally around the loop. In general, if the angle is negative it will result in a negative θPST, thus meaning less flow on PEC towards SA.<br><br>– The report notes that the loop flow constraint is not finalised:<br><br>   *The application of an inter-regional loop in the NEM is a new concept and therefore engineering assessment of the effectiveness of the constraint in representing power flows, and the effect of the PST, will continue. Please note AEMO may implement PEC differently to that represented above.*<br><br>– Section 2.2 of the report provides a description of how AEMO expects the PST tap position will be adjusted to optimise the utilisation of available transmission capacity. The process involves monitoring the head room available on PEC and Heywood interconnectors and adjusting the PST tap if one of the interconnectors looks to be approaching a limit and the other interconnector is further from a limit.<br><br>– The loop flow constraint only considered three set points for the PST -6.73°, 0° and 8°.<br><br>– Transgrid has confirmed that the PST provides a range of +/-40°. It is therefore clear that the loop flow equation developed by AEMO only considers approximately 20% of the available PST range. The loop flow constraint would need to be revised to capture the full range of the PST.<br><br>– The coefficients in the loop flow constraint appear to have been calculated for the power system that exists when stage 2 of PEC is commissioned. The loop flow constraint would need to be revised to consider the impact of future augmentations such as VNI West. |
| Jul 2023 | AEMO | PEC Integration | AEMO commissioned ACIL Allen to undertake market modelling to assess the need | AEMO engaged ACIL Allen to analyse the impact of PEC and the loop equality constraint on NEMDE. The modelling revealed that negative Inter-regional settlement residues (IRSRs) frequently occur due to transmission loop flows. While |

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|---|---|---|---|---|
| | | | for a rule change to manage negative settlement residues accrued across interconnectors. The model implements the loop flow constraint developed by AEMO as documented in the May 2023 updated Implementation Paper. | aggregate settlements around the loop are typically in surplus, certain interconnectors consistently accrue negative IRSRs.[21]

ACIL Allen added the loop flow constraint into their standard NEM reference case. As documented in section 3.1 of their report, ACIL Allen's reference case models thermal constraints from the 2020 ISP ESOO thermal constraint workbook and additional constraints not included in the ISP dataset which bind frequently historically.[22]

It is not clear from the model assumptions provided in the ACIL Allen report whether transmission projects identified as actionable in the ISP were included in the model. GHD assumes that transmission projects modelled were consistent with the Central case in the 2022 ESOO as ACIL Allen has adopted the ESOO network constraints. The 2022 ESOO[23] states that the Central scenario includes committed transmission augmentations[24]. It is therefore possible that the modelling did not consider the impact of VNI West.

ACIL Allen's modelling highlighted key settlement dynamics with the PEC loop flow equation developed by AEMO. Negative IRSRs are expected to become common, driven by loop flow constraints and intra-regional constraints, occurring in approximately 89–93% of cases. While the loop often results in negative IRSRs on one or two interconnectors, aggregate settlement residues around the loop remain positive or zero over 94% of the time.

The modelling shows that the frequency and value of net negative IRSRs is expected to be small but increase over time.

ACIL Allen's market modelling was used by AEMO to promote the need to reform the approach to managing negative residues.

The ACIL Allen report does not specifically comment on the impact of loop flows on the market benefits delivered by PEC.

ACIL Allen did include as finding that due to the loop constraint, PEC is going to be underutilised most of the time which is inconsistent with the proposed operational strategy of the PST.

We recommend care in extending to ACIL Allen modelling to draw conclusions regarding the impact of the loop flow equation on the market benefits for PEC. for the following reasons:

– The loop flow equation developed by AEMO only consider 20% of the available range of the PST and therefore may be inaccurate and not fully utilise PEC. The equation would need to be amended to accurately represent the full range of the PST.

– The loop flow equation does not consider the change to the network that will occur with other actionable projects such as VNI West. To accurately represent |

---

[21] PEC-Market-Integration-Directions-paper-for-consultation.pdf
[22] ACIL Allen Report modelling-the-settlement-effects-of-pec---final-report
[23] 2022-electricity-statement-of-opportunities.pdf
[24] VNI minor, PEC, QNI minor were modelled in the 2022 ESOO Central scenario

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|---|---|---|---|---|
| | | | | future conditions the loop flow equation would need to be revised to show the effect of actionable projects. |
| | | | | – The market modelling undertaken by ACIL Allen included an Optimal PST Setting scenario in which the optimisation engine was allowed to select which version of the loop flow equation was modelled. This approach intends to better reflect the impact of adjusting the PST to optimise dispatch. While this is a reasonable approach it is limited by the fact that the range of loop flow equations effectively only allow 20% of the PST range to be used. |
| | | | | On balance conclusions drawn from the ACII Allen modelling regarding the impact of the loop flow constraint on PEC utilisation and hence market benefits are likely to be pessimistic. |
| 2024 | Transgrid | Refreshed estimate of market benefits | Modelling being undertake by EY. | EY is using their Time Sequential Integrated Resource Planning Model to assess the benefits delivered by PEC:<br><br>– EY confirmed that the model uses an embedded DC load flow to model the underlying next work and ensure that power flows are consistent with the impedance of the branches in the network. The one exception is PEC which is modelled as a fully controlled link.<br><br>– The modelling approach allows the optimisation engine to dispatch flows across PEC that are independent of flows across the Heywood and VNI interconnect. Network constraints are implemented to ensure the power flow across PEC does not exceed expected network capability.<br><br>– The modelling approach assumes that the +/- 40º range of the PSTs at Buronga is sufficient to allow flows on PEC which are independent of flows on Heywood and VNI.<br><br>The modelling undertaken by EY risks overestimating the market benefits delivered by PEC. This could occur if achieving the combination of flows on PEC, Heywood and VNI in the market modelling results would require exceeding the range available with the PST.<br><br>Conversely if the combinations of power flows on PEC, Heywood and VNI extracted from the market modelling results are consistent with flows that can be achieved with the PST not being exceeded then it is unlikely that any material over-estimation of benefits have occurred. |
| Annually | AEMO | Production of ISP every 2 years and ESOO every year | ISP assesses market benefits of projects identified as actionable.<br><br>ESOO assessed reliability outcomes expected under a central scenario and variants on that scenario | AEMO undertakes market modelling using Plexos for the ISP and the ESOO. Even though PEC is a committed project in the 2024 ISP the market modelling completed by AEMO did not include any loop flow constraint.<br><br>The capacity outlook model used in the ISP models NSW as 4 sub-regions and SA with two sub-regions. In that model PEC is seen as a connection between the Southern NSW and Central SA sub-regions. There is no loop flow constraint in the model as such the model allow flows on PEC that are independent of flows on other interconnectors.<br><br>In contrast the time sequential model used in the ISP adopts a regional model with inter and intra- regional constraint equations. In this model PEC is incorporated into |

| Date | Entity | Purpose | Assess benefits and costs | Consideration of loop flows |
|---|---|---|---|---|
| | | | | two notional interconnectors. One running between Vic and SA and the other between Vic and NSW. This appears to be adopting the approach proposed in the 2016 NTNDP with Buronga assumed to staddle the NSW to VIC border. |
| | | | | The ISP and ESOO does not model PEC as establishing an interconnection between SA and NSW, but rather a project that alters the capacity of the NSW to Vic interconnection and the SA to Vic interconnection. |
| | | | | The time sequential models adopted in the ISP and ESOO don't reflect the market structure that retains Buronga in NSW. Nor does it model any explicit relationship between the flow on the PEC, VNI and Heywood. The model effectively assumes that flow between NSW and Buronga on PEC can be controlled independently to the flows from Buronga to Robertstown. |
| | | | | The approach adopted in the ISP and ESOO may overestimate market benefits if the flows on the interconnectors exceed those that can be achieved on the real power system by adjusting the taps on the PST. |

**GHD**

→ **The Power of Commitment**