



# AUSTRALIAN ENERGY MARKET OPERATOR

Independent Assurance Report:  
Compliance of AEMO's market software  
systems and processes for software  
management

## FINAL REPORT

9 December 2016

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**PA Regional Office:**  
PA Consulting Group  
Level 13, 142 Lambton Quay,  
Wellington 6011,  
New Zealand  
Tel: +64 4 499 9053  
Fax: +64 4 473 1630  
[www.paconsulting.com](http://www.paconsulting.com)

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**Prepared by:** Sue Paul, Tim Robinson, Jonathan Zukerman

# FOREWORD

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PA Consulting Group undertakes the Western Australian (WA) operational market audits which include:

- An Electricity Compliance Audit of the market operator<sup>1</sup> (*Audit 1*)
- An Electricity Software Compliance Audit of the market operator (*Audit 2*)
- A Gas Compliance Audit of the market operator<sup>2</sup> (*Audit 3*)
- An Electricity Compliance Audit of the system operator<sup>3</sup> (*Audit 4*).

This independent assurance report pertains to Audit 2 above and is part of a series of four audit reports. The reports in this series are:

- *Audit 1: Independent Assurance Report: Compliance of AEMO's internal procedures and business processes with the Wholesale Electricity Market Rules and AEMO's compliance with the Wholesale Electricity Market Rules and Market Procedures*
- *Audit 2: Independent Assurance Report: Compliance of AEMO's software systems and processes for software management*
- *Audit 3: Independent Assurance Report: AEMO's compliance with the Gas Services Information Rules*
- *Audit 4: Independent Assurance Report: System Management's compliance with the Wholesale Electricity Market Rules and Market Procedures*

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<sup>1</sup> Australian Energy Market Operator (AEMO) from the AEMO Transition Date as defined in the Electricity Rules (8AM, November 30th 2015); Independent Market Operator (IMO) prior to the AEMO Transition Date.

<sup>2</sup> Australian Energy Market Operator (AEMO) from the AEMO Transition Date as defined in the Gas Rules (8AM, November 30th 2015); Independent Market Operator (IMO) prior to the AEMO Transition Date.

<sup>3</sup> Australian Energy Market Operator (AEMO) from the System Management Transition Date as defined in the Electricity Rules (8AM, 1 July 2016); Western Power (System Management) (SM), prior to the System Management Transition Date.

# EXECUTIVE SUMMARY

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This independent assurance report sets out the results of the market audit by PA Consulting Group in carrying out its audit of the compliance of AEMO's market software and processes for software management with the Wholesale Electricity Market Rules (Electricity Rules) and Market Procedures (Electricity Procedures).

## Regulatory context and scope

The audit of AEMO's market software and processes for software management (referred to as Audit 2) is conducted under clause 2.14.3 (c) of the Electricity Rules, supplemented by transitional clause 1.14.7 which requires AEMO to ensure that for the first Market Audit following the AEMO Transition Date<sup>4</sup>, the Market Auditor audits both AEMO (for activities on and from the Transition Date) and the IMO (in respect of its activities before the Transition Date).

## Audit Period

The Audit Year is 1 August 2015 to 30 June 2016, both dates inclusive.

## Audited Entity

For avoidance of doubt, the Audited Entity for this audit is:

- The Independent Market Operator (IMO) prior to the AEMO Transition Date
- AEMO following the AEMO Transition Date.

## Approach

### Assurance

Our audit has been conducted in accordance with Australian Auditing and Assurance Standards Board's '*Framework for Assurance Engagements*', ASAE 3000 '*Assurance Engagements Other than Audits and Reviews of Financial Information*'.

- Our review of AEMO's software management processes and controls provides limited assurance under ASAE 3000.
- Our review of software changes and of market software compliance with the Electricity Rules and Electricity Procedures provides reasonable assurance under ASAE 3000.

### Risk ratings and materiality

#### Risk ratings

Audit findings are categorised as follows:

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<sup>4</sup> 30 November 2015.

**Table 1: Compliance Ratings for Audit Findings**

Compliance rating	Description
1	Instances of non-compliance with Electricity Rules and Electricity Procedures noted in audit
2	Findings that are not an instance of non-compliance, but pose compliance risk
3	Findings related to minor housekeeping issues that do not affect compliance risk

Risk rating descriptors for audit findings were set in consultation with AEMO and are based on AEMO’s corporate risk matrix (including definitions of impact).

**Table 2: Risk Ratings for Audit Findings**

Risk rating	Description
Critical 	Potential for catastrophic impact on dispatch, settlement or other market outcomes if not addressed immediately. Requires executive actions and monitoring at board level.
Significant 	Potential for major impact on dispatch, settlement or other market outcomes if not addressed as a matter of priority. Requires senior management attention with regular monitoring at executive meetings.
Medium 	Potential for moderate impact on dispatch, settlement or other market outcomes if not addressed within a reasonable timeframe. Requires management attention with regular monitoring.
Low 	Potential for minor impact on dispatch, settlement or other market outcomes if not addressed in the future. Requires team level attention with regular monitoring.

**Table 3: Risk rating matrix**

		Consequence of risks associated with finding				
		Immaterial	Minor	Moderate	Major	Extreme
Likelihood of risk manifesting if finding not addressed	Almost Certain	Medium	Medium	Significant	Critical	Critical
	Likely	Low	Medium	Significant	Critical	Critical
	Possible	Low	Medium	Significant	Significant	Critical
	Unlikely	Low	Low	Medium	Medium	Significant
	Rare	Low	Low	Medium	Medium	Significant

**Qualification of audit opinion**

In determining whether to qualify our opinion on whether AEMO and IMO have complied “in all material respects”, we have taken the following factors into account:

- Purpose and objectives of the market audit
- AEMO's overall objectives
- AEMO's risk matrix definitions of impact
- Financial impacts on participants
- The number of participants or other stakeholders affected
- The impact of an issue on market objectives such as transparency, equity and efficiency
- Whether or not an issue is systemic
- Whether or not an issue is recurring (from previous audits).

## **Audit activities**

We have approached the audit in two components, respectively examining:

1. AEMO's software management processes and controls and
2. Changes to the software itself.

With respect to the software management processes and controls we have:

- Examined the documented processes for software management
- Compared them to actual operational practices through interviews with AEMO staff and inspections of process records
- Reviewed the compliance of operational practices with the Electricity Rules
- Observed the replication of market outputs using a past version of market software to assess compliance with clause 2.36.1(b)<sup>5</sup>.

With respect to the software changes, we have:

- Reviewed all system changes implemented since the last audit;
- Assessed whether those changes have potential for material effect on prices and quantities;
- Reviewed whether or not those changes have been certified as required under the Rules;
- Reviewed all rule changes commencing since the last audit;
- Assessed whether a rule change requires a change to the systems; and
- Identified where those changes have not been implemented.

We conducted one field visit in September 2016 to interview AEMO staff and to walk through the software management processes.

## **Findings and recommendations**

### **Summary of audit findings**


AEMO has maintained IT processes and practices to a high standard during the Audit Period with no changes to the WEMS development process. While the transfer of IMO functions to AEMO has not yet resulted in changes to software management practices, changes are planned to better align processes and tools across all of AEMO's operations.

Table 4 summarises audit findings by compliance and risk rating.

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<sup>5</sup> Specifically, we have reviewed the replication of settlements results for November 2015, which were generated using Settlements version 3.4-9 (deployed into production on 22 September 2015).

**Table 4: Summary of audit findings classified by compliance and risk ratings**

Risk rating	Compliance rating		
	1	2	3
	0	2	0

**Key findings**

***Current integration testing process poses some risk of unanticipated change to business processes***

AEMO’s testing of new software releases is consistent with international good practice, and with other market and system operators. It includes agile development, automated unit test scripts, manually executed functional test scripts, and independent certification of releases potentially affecting market prices and quantities. In our view, it is sufficient to meet the ‘appropriate’ standard set by Rule 2.36.1(c).

Nevertheless, there still remains an opportunity for unanticipated consequences on production systems. During the Audit Period, we observed three instances where software releases introduced minor bugs or unexpected process changes into the production environment.

A common theme was the integration of software into the surrounding business process – for example, one case involved a change to way background publication process worked, introducing an extra manual step being required to publish settlement statements, which was missed the first time, and then a process update subsequently made.

We recommend AEMO reviews the integration testing component of its test practices to ensure that high standards are maintained in future, particularly in view of the significant changes planned for the next audit period.

***There is opportunity to improve the change and release management processes for software that is not core market systems***

AEMO has identified a number of tools which are external to the core market systems, but are still used in calculations with potential for material impact on market outcomes. These include spreadsheet-based tools which calculate the Maximum Reserve Capacity Price, the Relevant Level for intermittent generators, the Alternative Maximum STEM Price, and GSI Fees.

These tools are not subject to the same rigour of change and release management as the core market software. It can be difficult to determine when a version change occurs, control for inadvertent changes, or specify control points in the update process to manage compliance risk.

We recommend that these tools are formally catalogued, brought under formal source control, and have changes managed via AEMO’s normal change and release processes.

**Opinion**

**Opinion with respect to the compliance of the Audited Entity’s software management processes with the Electricity Rules**

*Subject to the inherent limitations set out in Section 1.3.4, based on the audit procedures we have performed and the evidence we have examined, nothing has come to our attention that causes us to believe that the Audited Entity’s processes for software management have not been compliant with the Electricity Rules and Electricity Procedures during the Audit Period in all material respects.*

**Opinion with respect to the compliance of the Audited Entity's software with the Electricity Rules and Electricity Procedures**

*Subject to the inherent limitations set out in Section 1.3.4, based on the audit procedures we have performed and the evidence we have examined, it is our opinion that the Audited Entity's core market software systems have correctly implemented the calculations embodied in the Electricity Rules and Electricity Procedures, in all material respects.*

**PA Consulting Group**



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A handwritten signature in black ink, appearing to read 'SJT', written over a light grey rectangular background.

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**Stephen James Thornton**

**Member of PA's Management Group**

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9 December 2016

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# 1 INTRODUCTION

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This chapter sets out the regulatory context for Audit 2 and our approach to performing the audit.

## 1.1 Regulatory context and scope

The requirement for the audit of the AEMO is set out in the Wholesale Electricity Market Rules (the Electricity Rules).

The table below provides further detail on the heads of power that mandate this audit.

Clause reference	Comment
2.14.1	Requirement for AEMO to appoint market auditor
2.14.2	Requirement for AEMO to ensure market audits are undertaken no less than annually
2.14.3	Defines the scope of the Audit to include: <ul style="list-style-type: none"><li>a. The compliance of AEMO's internal procedures and business processes with the Electricity Rules</li><li>b. AEMO's compliance with the Electricity Rules and Market Procedures<sup>6</sup></li><li>c. AEMO's market software systems and processes for software management<sup>7</sup>.</li></ul>
2.36.1	Defines obligations with respect to the AEMO's software management systems and controls; this provides the compliance criteria for Audit 2.
1.14.7 (Transitional)	Requires AEMO to ensure that for the first Market Audit following the AEMO Transition Date, the Market Auditor audits both AEMO (for activities on and from the transition date) and the IMO (in respect of its activities before the transition date)

This report covers our audit of AEMO and the IMO under Electricity Rule 2.14.3(c).

## 1.2 Audited Entity

For avoidance of doubt, the Audited Entity for this audit is:

- The Independent Market Operator (IMO) prior to the AEMO Transition Date
- AEMO following the AEMO Transition Date.

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<sup>6</sup> Market Procedures defined in the Electricity Rules will be referred to from here-on as Electricity Procedures.

<sup>7</sup> i.e. the compliance of the software with the calculations set out in the Electricity Rules, and the compliance of the software management processes with Clause 2.36.1 of the Electricity Rules.

## 1.3 Approach

### 1.3.1 Assurance

Our audit has been conducted in accordance with Australian Auditing and Assurance Standards Board's 'Framework for Assurance Engagements', ASAE 3000 'Assurance Engagements Other than Audits and Reviews of Financial Information'.

- We provide limited assurance under this standard with respect to our review of the Audited Entity's software management processes and controls provides limited assurance under ASAE 3000.
- We provide reasonable assurance under this standard with respect to our review of the Audited Entity's software changes and the compliance of AEMO's market software with the Electricity Rules and Electricity Procedures

### 1.3.2 Risk ratings and materiality

#### Compliance and risk ratings




Audit findings are categorised as follows:


**Table 5: Compliance Ratings for Audit Findings**

Compliance rating	Description
1	Instances of non-compliance with Electricity Rules and Electricity Procedures noted in audit.
2	Findings that are not an instance of non-compliance, but pose compliance risk
3	Findings related to minor housekeeping issues that do not affect compliance risk

Risk rating descriptors for audit findings were set in consultation with AEMO and are set out in Table 6.

**Table 6: Risk Ratings for Audit Findings**

Risk rating	Description
Critical 	Potential for catastrophic impact on dispatch, settlement or other market outcomes if not addressed immediately. Requires executive actions and monitoring at board level.
Significant 	Potential for major impact on dispatch, settlement or other market outcomes if not addressed as a matter of priority. Requires senior management attention with regular monitoring at executive meetings.
Medium 	Potential for moderate impact on dispatch, settlement or other market outcomes if not addressed within a reasonable timeframe. Requires management attention with regular monitoring.

Risk rating	Description
Low 	Potential for minor impact on dispatch, settlement or other market outcomes if not addressed in the future. Requires team level attention with regular monitoring.

Each finding has been categorised according to its impact and likelihood, using the matrix in Table 7, and AEMO’s standard impact definitions shown in Table 8.

**Table 7: Classification of Audit Findings**

		Consequence of risks associated with finding				
		Immaterial	Minor	Moderate	Major	Extreme
Likelihood of risk manifesting if finding not addressed	Almost Certain	Medium	Medium	Significant	Critical	Critical
	Likely	Low	Medium	Significant	Critical	Critical
	Possible	Low	Medium	Significant	Significant	Critical
	Unlikely	Low	Low	Medium	Medium	Significant
	Rare	Low	Low	Medium	Medium	Significant

**Table 8: AEMO impact ratings**

Type of impact	EXTREME	MAJOR	MODERATE	MINOR	IMMATERIAL
<b>Reputation &amp; Stakeholders</b>	Significant long-term damage to stakeholder confidence and relationships; total loss of public confidence; intensive adverse media exposure	Significant short term damage to stakeholder confidence and relationships; some loss of public confidence; adverse media exposure	Some damage to stakeholder confidence and relationships	Manageable reduction in stakeholder confidence	No lasting effects
<b>AEMO Financial Impact</b>	>\$25M	>\$5M-25M	>\$500K-\$5M	>\$100K-\$500K	<\$100K
<b>Safety</b>	Single fatality or permanent injury or widespread impact on public safety	Serious injury requiring hospitalisation >5 days or localised impact on public safety	Injury requiring <5 days hospitalisation or medical treatment	Medical treatment only	First aid
<b>Infrastructure, Assets &amp; Environment</b>	Permanent long term effect and or rectification not possible	Significant effect, difficult rectification	Measurable effect, easy rectification	Measurable effect, no rectification required	No measurable damage or effect
<b>Market</b>	Loss of supply to >50% of customer demand in any one jurisdiction or >25% across multiple jurisdictions Market suspension in one jurisdiction or market	Loss of supply to >25% of customer demand in any one jurisdiction or >10% across multiple jurisdictions Market suspension in one jurisdiction or market	Loss of supply to >10% of customer demand in any one jurisdiction or >5% across multiple jurisdictions Market operating in an administered state for > 5 days for gas market or >1 day for electricity market	Loss of supply to >5% of customer demand in any one jurisdiction or >2% across multiple jurisdictions Market operating in an administered state for <5 days for gas market or <1 day for electricity market	No restriction of supply No disruption to markets
<b>Legal &amp; Regulatory</b>	Imprisonment or fine >\$100 personal liability to officer or director of company Disqualification as officer/director Regulator or parliamentary inquiry with loss of market participants and public confidence	>\$100K personal liability to officer or director Disqualification as officer/director Regulator or parliamentary inquiry with substantial loss of reputation, financial cost, loss of stakeholder confidence, political impact	Fine of less than \$100K and no personal liability Regulator or government inquiry with loss of reputation or adverse government impact	Nominal fine Regulator or government inquiry resolved by routine management procedures	No fine No government or regulator inquiry

## Qualification of audit opinion

In determining whether to qualify our opinion on whether AEMO and IMO have complied “in all material respects”, we have taken the following factors into account:

- Purpose and objectives of the market audit
- AEMO’s overall objectives
- AEMO’s risk matrix definitions of impact
- Financial impacts on participants
- The number of participants or other stakeholders affected
- The impact of an issue on market objectives such as transparency, equity and efficiency
- Whether or not an issue is systemic
- Whether or not an issue is recurring (from previous audits).

### 1.3.3 Audit activities

We have approached the audit in two components, respectively examining:

3. AEMO’s software management processes and controls and
4. Changes to the software itself.

With respect to the software management processes and controls we have:

- Examined the documented processes for software management
- Compared them to actual operational practices through interviews with AEMO staff and inspections of process records
- Reviewed the compliance of operational practices with the Electricity Rules
- Observed the replication of market outputs using a past version of market software to assess compliance with clause 2.36.1(b) <sup>8</sup>.

With respect to the software changes, we have:

- Reviewed all system changes implemented since the last audit;
- Assessed whether those changes have potential for material effect on prices and quantities;
- Reviewed whether or not those changes have been certified as required under the Rules;
- Reviewed all rule changes commencing since the last audit;
- Assessed whether a rule change requires a change to the systems; and
- Identified where those changes have not been implemented.

We conducted one field-visit in September 2016 to interview AEMO staff and to walk through the software management processes.

All audit information (documentation, logs and system outputs) has been provided to us by AEMO’s Operations and IT team.

### 1.3.4 Inherent limitations and qualifications

As in previous years, we note that there are limitations to any external audit. Audits are not an absolute guarantee of the truth or reliability of agency information or the effectiveness of internal controls. They may not identify all matters of significance. This is because external audit techniques involve:

- Professional judgement as to “good industry and market operational practice”

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<sup>8</sup> Specifically, we have reviewed the replication of settlements results for November 2015, which were generated using Settlements version 3.4-9 (deployed into production on 22 September 2015).

- The use of sample testing
- An assessment of the effectiveness of internal control structures and
- An assessment of risk.

A market audit does not guarantee every procedure and action carried out in the operation of the electricity market in the audit report, nor does it examine all evidence and every transaction. However, our audit procedures should identify errors or omissions significant enough to adversely affect market outcomes.

Our opinion with respect to AEMO's compliance with the Electricity Rules and Electricity Procedures are therefore subject to the following caveats:

5. Our audit procedures did not include assessing irregularities such as fraudulent or illegal activities. As such, our audit should not be relied upon to disclose such irregularities. However, in the event that we were to detect any fraudulent or illegal activity, we would report this to AEMO. No such findings have been made during this audit.
6. Our audit is not designed to detect all weaknesses in control procedures as it is not performed continuously throughout the audit period and is performed on a sample basis. Specifically, our business process reviews assessing the use of controls were undertaken after the end of the audit period. As such:
  - d. Although our findings are indicative of AEMO's practices during the audit period, they do not constitute definitive evidence that AEMO applied those controls during the audit period.
  - e. Projections of our findings to future periods carry the risk that:
    - i. Controls may become inadequate over time due to changes in the Electricity Rules or AEMO's business processes, procedures and systems
    - ii. The degree of compliance with the control procedures we have reviewed deteriorates over time.

## 1.4 Structure of this report

The report is in two parts:

- Chapter 2 *Compliance of AEMO's software management processes and controls* reports on the compliance of the market software management processes with the Electricity Rules and Electricity Procedures
- Chapter 3 *Compliance of AEMO software* reports on the compliance of the market software with the Electricity Rules and Electricity Procedures.

## 2 COMPLIANCE OF AEMO'S SOFTWARE MANAGEMENT PROCESSES AND CONTROLS

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Appropriate management of the market software by AEMO is essential given the nature of the business risk to both AEMO and the Western Australia Electricity Market.

This chapter:

- Sets out the Audited Entity's obligations and procedures relating to software management under the Electricity Rules.
- Summarises changes to the Audited Entity's software management processes, procedures and tools since the previous market audit
- Summarises audit findings relating to the Audited Entity's compliance with software management obligations.

### 2.1 Audited Entity's software management obligations under the Electricity Rules

#### 2.1.1 Rules obligations

The Electricity Rules set out certain obligations with respect to AEMO's software management systems and controls.

The requirements set out in Electricity Rule 2.36.1 are:

*Where AEMO uses software systems to determine Balancing Prices, to determine Non-Balancing Facility Dispatch Instruction Payments, to determine LFAS Prices, in the Reserve Capacity Auction, STEM Auction or settlement processes, it must:*

- maintain a record of which version of software was used in producing each set of results, and maintain records of the details of the differences between each version and the reasons for the changes between versions;*
- maintain each version of the software in a state where results produced with that version can be reproduced for a period of at least 1 year from the release date of the last results produced with that version;*
- ensure that appropriate testing of new software versions is conducted;*
- ensure that any versions of the software used by AEMO have been certified as being in compliance with the Market Rules by an independent auditor; and*
- require vendors of software audited in accordance with clause 2.36.1(d) to make available to Rule Participants explicit documentation of the functionality of the software adequate for the purpose of audit.*

Rule 2.36.2 defines a 'version' as follows:

*A "version" of the software referred to in clause 2.36.1 means any initial software used and any changes to the software that could have a material effect on the prices or quantities resulting from the use of the software.*



## 2.1.2 Procedures

Although there are no relevant Electricity Procedures relating to this subject, there are three relevant Internal Procedures:

- Internal Procedure: IT Support Pack
- Internal Procedure: Software Configuration Management Plan and
- Internal Procedure: WEMS IT Disaster Recovery Plan.

## 2.2 Changes to software management processes and controls

AEMO has maintained IT processes and practices to a high standard. These robust processes and high levels of automation in market systems continue to be effective controls against compliance risk. No substantial changes to software management process and controls have occurred during the 2015/16 audit period.

AEMO has less ability to control settlement system development practices than it does for WEMS, as the settlement system is developed by a third party vendor, while WEMS is effectively developed in house by AEMO. Nevertheless, AEMO does have ability to manage some parts of the settlement system release lifecycle. Opportunities for further improvement still remain, particularly in the automation of deployments.

### 2.2.1 Changes to documentation, frameworks and tools

There were no substantive changes to the Software Configuration Management Plan or IT Support Pack internal procedures during the Audit Year. While the transfer of IMO functions to AEMO has not yet resulted in changes to software management practices, changes are planned to better align processes and tools across all of AEMO's operations.

Workflow processes in JIRA<sup>9</sup> are well established and applied consistently. A continuous build system implemented using Bamboo, automated testing using Junit, and automated certification regression testing using Cucumber (for WEMS and SPARTA) are also well established for the AEMO-developed software systems.

### 2.2.2 Changes to practice

The WEMS change, test and release cycle continues to perform well. AEMO has automated build and deployment activities, to the point where there is limited scope for manual error in the release process. No substantial changes to software management practices have occurred during the audit year; however, with the transfer of functions to AEMO, there will be a transition to existing AEMO (NEM) practices in the future.

Team staffing changes during the Audit Year have resulted in a reduction in test resources compared with previous years, with no dedicated test management role.

## 2.3 Compliance of software management processes with the Electricity Rules

### 2.3.1 General comment on the Audited Entity's compliance with clause 2.36.1

Subject to Section 2.3.2, AEMO's software management processes remain sufficient to comply with clause 2.36.1 of the Electricity Rules.

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<sup>9</sup> AEMO's workflow tool, used for development activities as well as operational support.

**Table 9: Comment on the Audited Entity's compliance with clause 2.36.1 of the Electricity Rules during the Audit Year**

Clause	Comment on compliance
2.36.1(a)	The Audited Entity has maintained a record of all versions of market software used together with their dates in service, details of the differences between each version and the reasons for the changes between versions. These take the form of release notes, JIRA records and database entries.
2.36.1(b)	The Audited Entity has maintained the ability to roll back versions of the market software by restoring previous database versions and re-installing previous versions of the software. AEMO was able to reproduce past results exactly for a sample case <sup>10</sup> .
2.36.1(c)	The Audited Entity has conducted appropriate testing on all new releases of market software prior to their being placed in service.
2.36.1(d)	The Audited Entity has ensured that all software versions are covered by an independent certification prior to implementation (subject to the observations noted in section 2.3.2).
2.36.1(e)	The Audited Entity has provided us with documentation on the functionality of the market software. AEMO also holds release artefacts including detailed release notes for each release. Given the degree of confidentiality over the software imposed by the vendors, PA accepts that the degree to which AEMO provides documentation is sufficient for compliance with this Electricity Rule clause.


### 2.3.2 Audit Findings

There have been no self-reported or other instances of non-compliance with clause 2.36.1 of the Electricity Rules.

Table 10 summarises audit findings by compliance rating and risk rating.



Table 11 provides details of audit findings that were classified as Compliance Rating 2 and 3.

**Table 10: Summary of audit findings classified by compliance and risk ratings**

Risk rating	Compliance rating		
	1	2	3
	0	2	0

<sup>10</sup> Specifically, the Settlements results for November 2015, which were generated using Settlements version 3.4-9 which was deployed into production on 22 September 2015.

**Table 11: Summary of Compliance Rating 2 & 3 Audit Findings**

Finding	Compliance & Risk Rating	Description
<p>Current process for testing software releases poses some risk of bugs and defects being missed</p>		<p>AEMO’s testing of new software releases is consistent with standard international practices, and with other market and system operators. It includes agile development, automated unit test scripts, manually executed functional test scripts, and independent certification of releases potentially affecting market prices and quantities. In our view, it is sufficient to meet the ‘appropriate’ standard set by Rule 2.36.1(c).</p> <p>AEMO’s testing of AEMO-developed software releases consists of:</p> <ul style="list-style-type: none"> <li>• A set of automated unit test scripts that are run automatically as part of the build process</li> <li>• A set of manually executed functional test scripts that are performed by specialist test staff</li> </ul> <p>The automated unit tests are run on every software build, so every version released into production will have had the full set of these tests run on it prior to release.</p> <p>A full set of manual functional tests is not generally run on the same software versions that are released into production. This is due to the agile development process that has been adopted by AEMO, which results in numerous and frequent software builds being generated prior to the release version. This process is in line with standard international practices for organisations of this type.</p> <p>While this process provides an adequate compromise between robust software testing and timely release of software changes, there still remains an opportunity for unanticipated consequences on production systems.. During the Audit Period, we observed three instances where software releases introduced minor bugs or unexpected process changes into the production environment. Two resulting market breaches, (described in our Audit 1 report) highlight the importance of rigorous software testing, in particular within an integrated environment.</p> <p>A common theme was the integration of software into the surrounding business process – for example, one case involved a change to way background publication process worked, introducing an extra manual step being required to publish settlement statements, which was missed the first time, and then a process update subsequently made.</p> <p>While these observations do not mean that AEMO does not carry out appropriate testing of market software releases, they do highlight increased risk of future non-compliance. We recommend AEMO reviews the integration testing component of its test practices to ensure that high standards are maintained in future, particularly in view of the significant changes planned for the next audit period.</p>
<p>There is opportunity to improve the change and release management processes for software that is not core market systems</p>		<p>AEMO has identified a number of tools which are external to the core market systems, but are still used in calculations with potential for material impact on market outcomes. These include spreadsheet-based tools which calculate the Maximum Reserve Capacity Price, the Relevant Level for intermittent generators, the Alternative Maximum STEM Price, and GSI Fees.</p> <p>For the purposes of compliance with the Electricity Rules, it is unclear whether these tools – many in spreadsheet form – are covered under the ‘market software systems’ referred to in clause 2.36.1. Nonetheless, AEMO has determined that as</p>

Finding	Compliance & Risk Rating	Description
		<p>part of prudent operation of the market, these tools should also be subject to certification where they meet the criteria in the Internal Procedure: Market Audits.</p> <p>These tools are not subject to the same rigour of change and release management as the core market software. It can be difficult to determine when a version change occurs, control for inadvertent changes, or specify control points in the update process to manage compliance risk.</p> <p>We recommend that these tools are formally catalogued, brought under formal source control, and have changes managed via AEMO's normal change and release processes.</p>

## 3 COMPLIANCE OF AEMO SOFTWARE

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This chapter sets out our findings with respect to the compliance of AEMO's market software with the Electricity Rules and Electricity Procedures.

The software systems covered by this section of the review are the core market systems<sup>11</sup>:

- The Reserve Capacity system;
- The Energy Market systems (including the Short Term Energy Market, the Balancing Market and the Load Following Ancillary Service Market); and
- The Settlement systems.

The chapter is structured as follows:

- Section 3.1 sets out PA's approach to certifying releases of market software (as required under clause 2.36.1(d) of the Electricity Rules).
- Section 3.2 summarises changes to core market systems (and other software as relevant) during the Audit Year
- Section 3.3 summarises our audit findings.

As independent certification testing is focused on areas of change, and does not necessarily include a full regression test of all functionality, our certification depends on the chain of testing completed since the most recent test of all functionality. For this reason, we include a summary of historical market software changes that have been certified prior to this Audit Period in Appendix 1.

### 3.1 Approach taken to certifying the market software

Software testing and certification under MR 2.36.1(d) is carried out on a release by release basis throughout the year. Hence, at the time of the annual market audit (this Audit 2), we rely upon the testing conducted throughout the year and our review of the Audited Entity's software release change log (and other documentation) to determine:

- Whether all changes to market software contemplated by clause 2.36.1(d) have been independently certified, and therefore
- Whether all market software contemplated by clause 2.36.1(d) is still compliant with the Electricity Rules and Electricity Procedures.

Below, we describe further the approaches that we use for auditing the compliance of market software with the Electricity Rules and Electricity Procedures.

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<sup>11</sup> Where a tool outside of the core market systems has been tested and certified, that certification is also covered.

### 3.1.1 Initial software testing

When AEMO notifies us of changes to market software or release of new software we adopt one or both of the following methods:

- Constructing independent models of the specific case. The model may perform a set of calculations (such as pre-processing of data or quantity allocations, as defined by the formulation), or it may include an optimisation procedure designed to replicate a portion of the software's formulation.
- Directly comparing the software results to our understanding of the formulation. This may involve answering questions such as:
  - Are the appropriate constraints binding?
  - Does the set of calculations change as we expect when input values are altered and the software is re-run?
  - Does the software make optimal trade-offs between alternative resources, given their costs and associated constraints?

In testing AEMO's market software, we use both approaches.

As much of the software tested is embedded in the market systems, PA specifies the tests to be performed (including input data requirements and output data to be provided) and AEMO staff conducts the tests on the market systems. PA then reviews the test results to determine whether the results are compliant with the requirements of the Electricity Rules and Electricity Procedures.

### 3.1.2 Assessment of software compliance at time of market audit

Once software has been tested and shown to be compliant, it is not necessary to retest the software unless:

- Changes have been known to be made to the software which render the previous testing no longer valid; or
- It is believed that unapproved changes have been made to the software.

The first circumstance is readily picked up where there is a rigorous software change control procedure. The second exists where such a change control procedure is lacking.

As part of the 2006-7 and 2007-8 annual audits of the IMO's market software systems we carried out full regression tests to verify that the market software systems comply with the requirements of the Electricity Rules and Electricity Procedures. Since the 2008-9 year, we have determined the compliance of the market software by:

- Examining the IMO's market software change procedures to ensure that they are robust
- Examining various records of changes made to the market software systems (including change process logs, release notes and system audit trails) to determine whether the changes required independent testing and certification
- Examining Electricity Rule and Procedure changes and assessing whether corresponding changes to market software have been implemented (where relevant) and
- Carrying out such testing and certification on those software changes as required.

Under this regime, if there are no changes made to the software since the last time it was certified, we may deduce that the software continues to comply with the Electricity Rules.

If changes are made to the software, we plan and conduct tests to exercise any new or changed calculations, and other calculations that are likely to have been affected.

This is in line with the approach we use when verifying software compliance in other jurisdictions.

This incremental approach provides a cost-effective means for providing assurance on compliance when changes to the market are incremental in nature, but it becomes less meaningful as time goes on and/or if major changes are introduced to the market.

## 3.2 2015-16 market software certification

### 3.2.1 Electricity Rules changes in the Audit Period

There were three Electricity Rule changes commencing between 1 August 2015 and 30 June 2016.

- No software changes were required in response to the RC\_2015\_05 (1 September 2015) which related to transitional provisions for the 2015 Reserve Capacity Cycle.
- WEMS release 3.13-981-1 was required in response to the transfer of IMO functions to AEMO as part of the 30 November 2015 rule change.
- WEMS release 3.16-1105-2 was required in response to the Reserve Capacity Mechanism changes in the 1 June 2016 rule change.

### 3.2.2 Certification of core market systems

There were seven releases of new market systems software, two releases of new settlement software and two releases of new metering software between 1 August 2015 and 30 June 2016.

Most changes maintained certification without additional testing, as they did not involve changes that would be expected to have material impact on prices or quantities. All releases having material impact on market prices or quantities were independently certified prior to release. The changes are set out in Table 12, along with the certification status of the software version. The list only includes releases implemented in the production environment, and does not include versions which were only implemented in a development or test environment.

**Table 12: Production software changes in the 2015-16 audit period**

System	Version number	Release date	Changes to calculations affecting market outcomes?	Certification status	Comment
Settlements	3.4.9	22/09/2015	No	Maintained	
WEMS	3.12-913-9	23/09/2015	Yes	Certified	Reimplementation of core calculation modules. No change to calculations themselves.
WEMS	3.12-913-35	28/10/2015	No	Maintained	
Settlements	3.4.12	2/12/2015	No	Maintained	IMO functions transferred to AEMO
WEMS	3.13-981-1	29/11/2015	No	Maintained	IMO functions transferred to AEMO
WEMS	3.13-981-6	13/01/2016	No	Maintained	
Metering	11.0.25	09/02/2016	No	Maintained	
WEMS	3.14-1016-3	3/03/2016	No	Maintained	
WEMS	3.14-1016-4	14/03/2016	No	Maintained	
Metering	11.0.27	24/05/2016	No	Maintained	
WEMS	3.16-1105-2	25/05/2016	Yes	Certified	RCM changes implemented for 1 June 2016 rule change.

Where the above software is designated 'Certified', it has either been independently tested by PA, or AEMO testing has been reviewed and accepted by PA. PA has then certified that the software complies with the requirements of the Electricity Rules.

### **3.2.3 Certification of tools outside core market systems**

Only one supporting tool (SPARTA v1.5, 27 November 2015) received certification during the audit period.

## **3.3 Audit findings**

We have reviewed the relevant AEMO IT system change control logs (including release notes, JIRA records, and database logs) and have confirmed that, other than the changes set out in section 3.2, the core market systems and the non-core market software referenced in Section 3.2.3 have not been materially changed since the referenced tests were performed.

As such, as at the time of the market audit, we found all market software (contemplated by clause 2.36.1(d)) and non-core market software referenced in Section 3.2.3 to be compliant with the Electricity Rules and Electricity Procedures, in all material respects.

Hence, we have no audit findings relating to this chapter.



# A HISTORICAL MARKET SOFTWARE CERTIFICATION PRIOR TO THE 2015-16 AUDIT PERIOD

This section provides a summary of the relevant certification tests previously conducted on the core AEMO market software systems along with the results of those tests. The core market software systems are comprised of:

- WEMS – Wholesale Electricity Market Systems, a software system developed and maintained by AEMO, and incorporating proprietary components provided by ABB
- POMAX Settlements – a software system provided by the vendor Brady Energy
- POMAX Metering – a software system provided by the vendor Brady Energy

WEMS certification relies on the chain of certification testing back to the comprehensive testing conducted in 2007-8. We conducted comprehensive testing of new WEMS components for the introduction of balancing and load following markets in 2012.

Settlements certification is based on the chain of certification testing back to the comprehensive testing conducted in 2014 for the new settlements version 3.4.6.

For the 2008-2011 audit periods, the information presented is organised around the tests conducted and sets out:

- The features of Market Systems software which have been tested;
- The nature of the tests conducted.

For the 2011-2015 audit periods, we set out the specific market software component releases, and their certification status. Releases with certification status of 'maintained' did not require additional testing, as they did not involve changes that would be expected to have material impact on prices or quantities.

**Table 13: Summary of previous tests conducted 2008-2011**

System	Subject	Test	Result	Year
Market Systems	STEM & Non-STEM	STEM ST1: Two Participants	PASS	2008
		STEM ST2: Multiple Optima Clearing Quantities	PASS	2008
		STEM ST3: Multiple Optima Clearing Prices	PASS	2008
		STEM ST4: Price set at Min-STEM price by default bid	PASS	2008
		STEM ST5: Price set at Alt-Max-STEM price by default bid	PASS	2008
		STEM ST6: Bilateral position outside of Price Curve	PASS	2008
		STEM ST7: Three Participants	PASS	2008
		NST 1 Dispatch Merit Order	PASS	2008
		NST 2 Dispatch Instructions	PASS	2008
		NST 3 Administered Balancing Prices	PASS	2008
		NST 4 Reserve Capacity Obligation Quantities		

System	Subject	Test	Result	Year
Market Systems	Non-STEM	Maximum Alternative Maximum Stem Price calculation	PASS	2008
Market Systems	Non-STEM	Incremental Reserve Capacity Ratio calculation	PASS	2008
Market Systems	Non-STEM	Prudential Requirements calculation	PASS	2008
Market Systems	STEM & Non-STEM	Change to the resource plan calculation	PASS	2009
Settlement	Other Settlement	Settlement of intermittent load generators	PASS	2009
Market Systems	Reserve Capacity	Supplementary Reserve Capacity calculation	PASS	2009
Market Systems	STEM	Inclusion of more than 50 participants in STEM auction and dispatch merit order calculations	PASS	2011

**Table 14: Production software changes in the 2011-15 audit periods**

System	Version number	Changes to calculations affecting market outcomes?	Certification status
WEMS	2.6.6	No	Maintained
WEMS	2.6.7	Yes	Certified
WEMS	2.6.8	No	Maintained
WEMS	2.7.37	No	Maintained
WEMS	2.7.39	No	Maintained
WEMS	2.7.41	No	Maintained
WEMS	2.8.28	No	Maintained
WEMS	2.8.29	No	Maintained
WEMS	3.0.18	No	Maintained
WEMS	3.0.21	Yes	Certified
WEMS	3.1.36	No	Maintained
WEMS	3.1.41	No	Maintained
WEMS	3.1.43	Yes	Certified
WEMS	3.1.44	Yes	Certified
WEMS	3.1.45	No	Maintained
WEMS	3.2.8	No	Maintained

<b>System</b>	<b>Version number</b>	<b>Changes to calculations affecting market outcomes?</b>	<b>Certification status</b>
<b>WEMS</b>	3.3.12	No	Maintained
<b>WEMS</b>	3.4.11	Yes	Certified
<b>WEMS</b>	3.5.6	Yes	Certified
<b>WEMS</b>	3.6.12	Yes	Certified
<b>WEMS</b>	3.6.13	No	Maintained
<b>WEMS</b>	3.6.15	No	Maintained
<b>WEMS</b>	3.6.16	No	Maintained
<b>WEMS</b>	3.7.9	No	Maintained
<b>WEMS</b>	3.7.12	No	Maintained
<b>WEMS</b>	3.7.13	Yes	Certified
<b>WEMS</b>	3.8.5	No	Maintained
<b>WEMS</b>	3.8.6	No	Maintained
<b>WEMS</b>	3.9.2	Yes	Certified
<b>WEMS</b>	3.9.2 (AS-2456)	Yes	Certified
<b>WEMS</b>	3.10.99-15	Yes	Certified
<b>WEMS</b>	3.10.99-59	No	Maintained
<b>Metering</b>	11 update 14	Yes	Certified
<b>Metering</b>	11.0.20	No	Maintained
<b>Settlements</b>	3.4.6	Yes	Certified
<b>Settlements</b>	3.4.7	No	Maintained
<b>Settlements</b>	3.4.8	Yes	Certified
<b>WEMS</b>	3.10-99-63	No	Maintained
<b>WEMS</b>	3.10-99-71	No	Maintained
<b>WEMS</b>	3.11.374-57	No	Maintained
<b>WEMS</b>	3.11.374-63	No	Maintained
<b>WEMS</b>	3.11.374-81	No	Maintained
<b>WEMS</b>	3.11.374-84	No	Maintained
<b>WEMS</b>	3.11.374-94	No	Maintained

<b>System</b>	<b>Version number</b>	<b>Changes to calculations affecting market outcomes?</b>	<b>Certification status</b>
<b>WEMS</b>	3.11.374-116	No	Maintained
<b>WEMS</b>	3.11.374-128	No	Maintained



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### **Corporate headquarters**

123 Buckingham Palace Road  
London SW1W 9SR  
United Kingdom  
+44 20 7730 9000

**paconsulting.com**

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