Five Minute Settlement Working Group:
Working Paper No. 2:
Design choices, implementation and transition

1 December 2016

1. Introduction

The AEMC is currently assessing the Five Minute Settlement rule change request submitted by Sun Metals Corporation. The proposal seeks to align the dispatch and settlement intervals in the wholesale electricity market in order to improve market efficiency.

The AEMC has already undertaken one round of consultation on the proposal and continues to meet with a wide range of stakeholders. An important part of our ongoing consultation is a Working Group that we have convened to assist in our assessment of the proposal. The first meeting of this group was held on 12 October 2016.

This paper has been prepared to stimulate discussion at the second meeting of the Working Group. It covers the key design choices and implementation of 5-minute settlement, as well as issues relating to a transition from the existing arrangements.

This paper should be read in conjunction with the first Working Group paper, which covered the materiality of the problem and how participants may respond to a 5-minute price signal.

While we have not yet come to a conclusion on the issues raised in the first Working Group paper, we are seeking to explore implementation issues to assist the Commission in making a decision on the rule change request. The objective of the second meeting is to discuss the most feasible implementation options and transition process if 5-minute settlement were to be adopted. Understanding the implementation issues will help with the quantification of the potential costs of the changes. These costs will feed into the Commission's assessment of whether the rule change would be in the long term interests of consumers.

This paper has been prepared as an AEMC staff paper and does not have the same status as a formal AEMC publication. It may not reflect the views of the AEMC's Commissioners.

Some stakeholders have asked that we include an additional round of consultation before publishing a draft determination. We would like to understand whether this would be valued by stakeholders and whether it is worth extending the project to accommodate this.

Throughout this process, we encourage stakeholders to provide feedback, including complementary or competing analysis that can help us in making our decision.

This working paper is structured as follows:

- **Section 2** explores the key design choices of 5-minute settlement.
- **Section 3** considers a range of implementation issues, including settlement for demand side participants, a mechanism to manage any settlement residue, systems changes, and other potential changes to the rules.
- **Section 4** discusses contract market impacts and the potential length of a transition period.
- **Section 5** covers the next steps of the AEMC's process.

2. Key design choices

Under s. 91A of the National Electricity Law (NEL) the Commission may make a "more preferable rule" if it is satisfied that having regard to the issues raised in the rule change request, the more preferable rule will or is likely to better contribute to the achievement of the national electricity objective (NEO) than the original proposal. With this in mind, and to help assess the request more broadly, we are considering different ways in which 5-minute settlement could be implemented.

The key design choices relate to the "optionality" afforded to demand side participants, and the data source used for 5-minute settlement. These choices are explored in this section.

Some stakeholders have suggested that dispatch and settlement could be aligned at an interval other that 5-minutes, such as 15-minutes, 30-minutes, or even 1-minute. For example, the dispatch interval could be increased to 15-minutes and trading interval reduced to 15-minutes. We have not considered any changes to intervals other than moving the trading interval to 5-minutes. In comparison to 5-minute alignment, alignment at other intervals would involve much larger changes and are therefore less likely to provide a net benefit to the market. For the purposes of the discussion in this paper, the implementation being explored is assumed to be 5-minute alignment.

2.1. Demand side optionality

Sun Metals' proposal involves 5-minute settlement that is compulsory for supply side participants but optional for the demand side of the market (i.e. retailers and large users can be settled on either a 5-minute or 30-minute basis). The alternative option is for demand side participants to be settled on a 5-minute basis.

As background, we note the reason demand side optionality first appeared in NEMMCO's proposed solution in 2002.[1] The perceived benefit in comparison to a compulsory arrangement was that it would avoid all participants having to implement 5-minute metering. It is unclear whether this implementation envisaged 5-minute metering for residential and small business customers. It was acknowledged at the time that demand side optionality had a range of drawbacks. These were:

- additional complexity in the market design from having settlements on different intervals and a new settlement residue; and
- that demand side participants would only receive the 5-minute price if they opted-in to 5-minute settlement.

[1] NEMMCO, *Anomalies in the NEM Due to Five-Minute Dispatch and Thirty-Minute Settlement*, Issues and Options paper, 3 September 1999.

These same concerns were raised in response to the AEMC's recent consultation paper, with most stakeholders opposed to demand side optionality. Generators and retailers consider this to be the most problematic aspect of the proposal. They are of the view that both sides of the market should be "equal" and that the AEMC should "retain symmetry" if it is to make a rule. It was also suggested that if 5-minute settlement is not compulsory initially for the demand side, it should be phased in over time.

Issues with demand side optionality

The issues with optionality identified by stakeholders and AEMC staff relate to:

- risk management and contract market liquidity; and
- general complexity and administrative burden.

The risk management concern relates to the prospect of the two sides of the market - supply and demand - being settled on a different basis. If there is optionality and some portion of the demand side continues to be settled on a 30-minute basis there could be situations of a 30-minute settled load seeking to contract with a 5-minute settled generator. This situation could also exist internally for vertically integrated businesses.[2] Such an arrangement would be an imperfect hedge and one party would be exposed to "basis risk".

Stakeholders have indicated concerns that demand side optionality would split contract market liquidity between 5-minute and 30-minute products. Changes in liquidity may affect contract prices and hence may impact on competition in upstream and downstream markets, such as the retail electricity market.

Further concerns relate to the settlement residue arising from differentiated settlement intervals. Notwithstanding the potential complexity of the mechanism required to recover and manage this (discussed in section 3.1 below), demand side participants could face a risk from having to pay the residue through an "uplift" on the spot price.[3] It is unclear whether participants would need to hedge against this risk, and whether this would be possible to do. Alternatively, the residue could be combined with existing settlement residues, though the consequences of doing this would need to be worked through in some detail.

The complexity of demand side optionality would be associated with AEMO, and retailers too if they were to offer 5-minute settlement to their customers, operating concurrent internal processes to accommodate both 5-minute and 30-minute

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2 While the proposal allows for retailers to opt-in to 5-minute settlement so to avoid a situation like this, in most cases opting-in wouldn't be a "quick fix" due to the data requirements of such an arrangement.

3 As discussed later in section 3.1, AEMO is likely to be in deficit rather than surplus in these circumstances, since generators are likely to be able to take advantage of the variability in the 5-minute price to earn more than the demand side pays if it is settled on a 30-minute basis.

settlements. One wholesale participant submitted that risk management would be more complicated if some customers are settled on a 5-minute basis and others on 30-minutes. Whether this complexity would be sufficiently different to the existing arrangements requires further investigation.

Compulsory 5-minute settlement

Generators and retailers are of the view that the AEMC should "retain symmetry" if it is to make a rule. This has been acknowledged by other stakeholders as well, though one large user representative submitted that 5-minute settlement must be "opt in" for the demand side.

The inference made by stakeholders is that an "equal" implementation of 5-minute settlement would address the contracting issues and general complexity identified above. While this is an attractive proposition, it is not immediately clear what this implementation would look like, especially in terms of how such an arrangement would work from a metering perspective. Under the market rules, symmetry would be retained if all Market Participants continue to be settled on the same basis. This category is referenced in the existing settlement arrangements in Chapter 3 of the National Electricity Rules (NER).

The category of Market Participant that demand side participants are likely to be registered as is the Market Customer category. Retailers and end users who buy electricity at the spot price must be registered with AEMO as Market Customers. There are currently a total of 71 Market Customers registered in the NEM.[4]

Implementing compulsory 5-minute settlement at the Market Customer level would avoid small customers with accumulation metering having to be metered on a 5-minute basis. Accumulation metering is only read at 3 month intervals. This section of the market is currently profiled, in aggregate for each distribution network region, to 30-minute intervals so that the market can be settled on a 30-minute basis. 5-minute settlement could be implemented through a 5-minute profile, if an acceptable profiling methodology can be decided upon. A solution would also need to be found to deal with customers that are currently metered on a 30-minute basis.

Depending on how it is implemented, compulsory 5-minute settlement could seemingly address the basis risk, settlement residue risk and contract market liquidity concerns. However, the metering and data requirements would be more substantial compared to optional 5-minute settlement. These issues are discussed further in sections 2.2 and chapter 3.

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4 AEMO, *Registration and Exemption List*, accessed 3 November 2016.

2.2. Five-minute data

In the rule change request, it was proposed that AEMO would calculate 5-minute settlement amounts using existing data sources. The sources would be 30-minute metered data and operational data from supervisory control and data acquisition (SCADA) systems. Alternatively, participants could choose to install 5-minute metering instead of using SCADA data.

We see three options on the question of 5-minute data:

a) SCADA profiling only;

b) optional SCADA or revenue metering (Sun Metals' proposal); and

c) revenue metering only.

For clarity, the SCADA-only option, option A, doesn't allow for any participants to provide 5-minute resolution metering data for settlement. Conversely, option C doesn't allow for SCADA profiling, so all participants settled on a 5-minute basis would need to provide 5-minute revenue-quality data. Option B would allow participants to choose between SCADA or 5-minute metering data. These options present different levels of cost and complexity, which also depend on whether 5-minute settlement is optional for the demand side.

SCADA profiling

SCADA is an industry term that is not explicitly defined in NER. AEMO considers this to mean remote control and monitoring devices, as described in clause 4.11.1 and in schedules 5.2, 5.3 and 5.3a of the NER.[5] In the context of this rule change, SCADA refers to remote monitoring devices. This distinction is important since remote monitoring is much cheaper to implement that remote control functionality.

The differences between revenue metering and SCADA are explained in the AEMC's consultation paper. For reference, the comparison table is provided here.

Table 1: Revenue metering versus SCADA

Point of comparison	Revenue metering	SCADA
Current application	To measure electricity consumption or production for the purpose of financial settlement	To monitor and control the power system in real time
Unit of measurement	Energy (e.g. MWh)	Power (e.g. MW)

5 AEMO, consultation paper submission, p3.

Typical measurement	30 minutes	4 seconds
Accuracy standard	Specified by Australian Standard	No common accuracy standard
Typical accuracy	0.5 to 1% (for scheduled generating units)	2 to 4%
Procedures for missing data	Defined by AEMO Procedures	State estimation or manual techniques

The proposed process for profiling metering data with SCADA measurements is also explained in the AEMC's consultation paper.[6] To summarise, the process involves calculating a profile of six percentage values for each half hour period. Each percentage value would be the average 5-minute energy, derived from SCADA measurements of power (MW) at generating units, divided by the total energy from the whole half hour, also from SCADA. The profile would be applied to the 30-minute metered energy to allocate the energy to each 5-minute period. That is, the total across the 30 minutes would be the same but it would be allocated differently between the 5 minute intervals.

The main benefit of the SCADA profiling implementation is that it would involve a relatively low level of cost and inconvenience since it would be implemented by AEMO using existing data. The process used by AEMO could be similar to the way in which contribution factors are calculated for FCAS "causer pays".[7]

On the other hand, the potential drawbacks associated with the SCADA implementation include:

- data integrity;
- data availability; and
- its suitability for demand side participation.

In the consultation paper we noted potential issues with the accuracy and reliability of SCADA data. These were cited by all generators as a reason why the SCADA profiling implementation option should not be used. In contrast, AEMO and several others saw this as a workable solution.

Having considered these issues, the SCADA profiling implementation may be workable for supply side settlement from a data integrity perspective. The following points support this position:

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6 Consultation paper, pp14-16.

7 AEMO, *Causer Pays Procedure*, 15 December 2013.

- As AEMO indicated in its submission, SCADA data is widely used in the central dispatch process for important functions which ultimately determine the spot prices of energy and frequency control ancillary services (FCAS). While SCADA is acknowledged as being less accurate than metering data (2-4% tolerance versus 0.5-1% for Chapter 7 meters), this accuracy appears adequate for the profiling process. Profiling ensures that energy is not "created" or "destroyed" - the volume of energy used in settlement will continue to be determined by a Chapter 7-compliant meter.[8] For this reason also, it appears that SCADA profiling is likely to be consistent with the National Measurements Act. It would be analogous to the adjustment that AEMO already makes in relation to Marginal Loss Factors.
- Missing or erroneous SCADA readings could be removed in the case of small gaps (perhaps, if a majority of the 75 readings per 5-minutes are still valid), or substituted using "state estimation"[9] or the last available value deemed to be valid. Failing this, the fall-back would be to use the simple average of the 30-minute metering data.[10] The AEMC is investigating the feasibility of 5-minute profiling arrangement using some combination of these contingency options. The feasibility of this approach will depend on:
    - whether it can provide a sufficient level of validation and verification; and
    - if it can be implemented without major changes to exiting SCADA equipment.

  We welcome suggestions from stakeholders as to the analysis that would be required to establish whether SCADA profiling can be sufficiently robust in the case of missing and erroneous data.
- Differences in the location of SCADA monitoring at power stations can lead to different bases for the measurements determining the SCADA profile. We understand that SCADA may exist for "as-generated" and/or "sent-out" power. The difference between these is the auxiliary (internal) loads of the power station. The location of SCADA monitoring would only pose a problem for SCADA profiling if auxiliary loads vary materially over a half hour interval, *after* a

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8 Chapter 7 of the NER sets out the requirements of metering installations, including their accuracy, testing and audit requirements, and the security of metering data.

9 State estimation can be thought of as a consensus view on the state of the power system at a point in time. It involves taking many measurements from points in the network so that there are multiple ways to calculate individual variables. In the raw data there will be errors associated with individual measurements. The state estimate is a solution that minimizes the errors across the whole system. The redundancy in input measurements provides some protection against outages and erroneous measurements at individual units. However, the state estimator is currently only run every 1-minute, so for any 30-minute period there would be a maximum of 31 data points that could be used for the profile (compared to 400-500 raw SCADA readings for the same period). Also, the coverage of the state estimator is not universal and values are not available for every point in the NEM.

10 Some compliance initiative may be required to ensure that SCADA data is not "lost" in situations where 30-minute settlement would be more favourable.

generator has synchronised with the network. We welcome stakeholder input on whether this is likely to occur.

Data availability appears to be an issue in the case of non-scheduled generators. Recently, the AEMC commissioned an analysis of 5-minute generation and load data for the non-scheduled generation and load in central dispatch rule change.[11] During this exercise it was discovered that the 5-minute resolution data was only available for a very small number of non-scheduled generators, potentially because SCADA is only required under the NER for new generators greater than 30MW.[12] This suggests that either the installation of SCADA or metering changes (i.e. reconfiguration) would be required for many non-scheduled generating units if they are to be settled on a 5-minute basis.

The final issue regarding the SCADA implementation is its suitability as a means for individual demand side participants to be settled on a 5-minute basis. In submissions, AEMO and some storage proponents suggest that the drafting of the SCADA implementation should be sufficiently broad so that granular data from non-Chapter 7 devices could also be eligible. It was noted by some that high-resolution data (e.g. 1-minute) is already available in some commercial and residential applications, such as building management systems and the operation of embedded batteries. A process for AEMO to receive and use this data would be additional to any profiling used for accumulation and existing interval metered consumers in the case of compulsory 5-minute settlement at the Market Customer level.

A potential issue with using this data to settle individual commercial and residential customers on a 5-minute basis is that there would be no way of confirming the veracity of the data used for profiling. The Commission welcomes stakeholders' views on this matter of profiling individual small consumers using granular data from non-Chapter 7 devices.

5-minute revenue metering

The other potential source of 5-minute data is from Chapter 7-compliant meters. As mentioned at the beginning of this section, this implementation could occur in conjunction with the SCADA implementation, or instead of it.

The reasons for using 5-minute revenue metering are that it would:

- overcome the data integrity and data availability issues noted above; and
- be a more suitable means for demand side 5-minute settlement.

The reasons against using 5-minute revenue metering are the potential costs due to:

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11 EY, *Non-scheduled generation and load in central dispatch rule change request*, 5 September 2015.

12 NER, Chapter 5.

- the need to reconfigure or replace metering for those participating in 5-minute settlement, which would include all the generation meters if SCADA profiling is not used and 5-minute metering is compulsory; and
- Metering Data Providers (MDPs), AEMO and others needing to change systems and processes to accommodate more granular data.

To provide some context, the following table provides an indication of the number of meters in the NEM by meter type and meter class.[13] The energy thresholds refer to the annual energy transfer for each metering type. For context, a typical household consumes around 5 MWh per year, a 100 MW wind farm may generate 300 GWh per year, and a 1,000 MW coal generator 8,500 GWh per year. "Wholesale" is a classification that captures meters associated with transmission connection points.

Table 2: Number of active Type 1-4 NMIs in the NEM

Meter class	Type 1 >1,000GWh	Type 2 100-1,000GWh	Type 3 0.75-100GWh	Type 4 <750 MWh	Total
Generation	120	285	159	126	690
Load	8	245	15,590	101,225	117,068
Wholesale	44	1,117	631	75	1,867

Through discussions with stakeholders, we understand that most meters that are less than 10 years old are capable of being reconfigured remotely to provide 5-minute resolution data. Further, we are informed that commercial and industrial (C&I) customers tend to change metering whenever they change retailers, which is typically every few years.[14] On the other hand, generators and network businesses tend to retain metering for longer periods, such as 10 to 15 years, or longer. Considering this, it appears likely that a large proportion of interval meters in the NEM can be remotely reconfigured to provide 5-minute data.

The next consideration is the data storage requirements of interval meters. Rule 7.3.1(a)(10) of the NER requires interval meters to locally store 35 days' worth of data.[15] We understand that interval meters typically have significantly more data storage capacity than is required for 35 days of history. The extra space is used for discretionary features, such as multi-part tariffs, calendars and power quality. In the short term, 5-minute data could potentially be accommodated by limiting the amount

13 This is a count of active National Metering Identifiers (NMIs). In some cases there may be multiple meters associated with a single NMI. For example: C&I customers may separately meter loads at a site that are aggregated for settlement at the NMI; high voltage meters may be duplicated for accuracy and redundancy purposes; and residential customers with solar PV that is gross metered may also have 2 meters.

14 In the year ending 30 September 2016, switching was recorded for close to 17,500 large NMIs. This equates to just over 20% of large NMIs in the NEM. The "large" classification is based on jurisdictional definitions.

15 The 35-day requirement is for meter types 1, 2, 3 and 4. Type 5 meters are interval meters but are required to locally store 200 days' worth of data because they are manually read.

of discretionary data that is collected. Over time, new meters with larger storage capacities could be deployed.

Despite this, it is possible that some existing meters may still have insufficient storage capacities to store 35 days' worth of 5-minute data. This could be addressed by upgrading the storage capacity of the meter, which would be possible if the hardware configuration of the meter allows for the storage component to be swapped out. Alternatively, the meter could be replaced. We understand that the installed cost (including labour) of a straight-forward meter replacement at a generating unit would be in the order of $2,000-5,000 for a single meter.

The Commission would like to know from stakeholders how many meters are likely to have insufficient storage capacities and require replacement. If many meters are affected, then a potential relaxation of the 35-day storage requirement could be considered as part of this implementation option.

A potentially more costly implication of the 5-minute metering option is the changes that might be required by AEMO, MDPs and others to process the 5-minute data. In comparison to the SCADA implementation, 5-minute metering affects more data interfaces and more participants. This is discussed in Chapter 3.

Summary: Metering options

The options discussed here are 5-minute settlement based on SCADA profiling of metering data only, providing the option between SCADA profiling or 5-minute revenue metering, or only catering for 5-minute revenue metering. SCADA profiling may be workable for supply side settlement, but further work is required to determine whether new provisions are required to ensure the data is of sufficient quality. The impact of any changes on existing SCADA collection and processing also needs to be taken into account. A limitation of this approach is the lack of SCADA data for non-scheduled generators.

A 5-minute metering implementation overcomes any data integrity concerns and would likely be a more effective means for non-scheduled generators and end users to be settled on a 5-minute basis. To accommodate the different circumstances, it may be desirable to accommodate both the SCADA and 5-minute metering options. Of the three options, this would be the most expensive to implement as it involves changes to systems and process to accommodate both regimes. The additional costs would need to be balanced against the benefits that may be possible from providing flexibility to participants.

3. Implementation issues

The section discusses issues that will need to be addressed to implement settlement on a 5-minute basis. The first of these is a mechanism to recover and manage the settlement residue if 5-minute settlement is optional for the demand side. An alternative identified above is for all participants to be settled on a 5-minute basis. Potential arrangements for this to occur for demand side participants are considered in section 3.2. Following this we discuss potential systems changes for different participants in the market. Finally, we comment on other, potentially complementary changes suggested by stakeholders during this process.

3.1. Settlement residue

In the AEMC's consultation paper, we provided a stylised example to show how, in situations where energy output or consumption varies *within* a half hour, settlement outcomes for 5-minute versus 30-minute settlement can be quite different.[16] These discrepancies would create a settlement residue if there is demand side optionality, and some portion of the demand side continues to be settled in a 30-minute basis. A new mechanism may be required to deal with this.

For the reasons set out in section 2.1, we prefer an implementation that doesn't involves demand side optionality and a new settlement residue. Notwithstanding this, we provide some thoughts on how such an arrangement could work.

The settlement residue would manifest as a discrepancy between money paid by consumers and the money owed to generators. In specific situations, the residue could be either positive (i.e. a surplus for AEMO from consumers paying more than is owed to generators) or negative (i.e. a deficit for AEMO from consumers paying less than is owed to generators). Over longer periods, it is expected that AEMO will be in deficit if there is demand side optionality. Generators that vary their output in response to 5-minute prices will earn more than the demand side pays if it is settled on a 30-minute basis.

One way of assessing the residue from historical data is to compare regional 30-minute prices and demand with the equivalent 5-minute data. Table 3 shows the result of this calculation (residue = 5-minute revenue - 30-minute revenue), summed for each of the past four financial years and for each NEM region. The result is indicative of the order of magnitude of the historical residue. All the values are positive, which says that, all other things equal, supply side revenues would have been higher under 5-minute settlement. We note that these sums are very small compared to the total value of electricity traded in the NEM, which is in the order of $8-10 billion a year.

16 Consultation paper, pp18-19.

Table 3: Indicative settlement residue 2012/13 to 2015/16

Fin year	NSW	QLD	SA	TAS	VIC
2012/13	$0.8m	$3.4m	$4.2m	$0.3m	$2.3m
2013/14	$0.4m	$2.5m	$1.7m	$0.3m	$1.1m
2014/15	$1.0m	$4.9m	$3.0m	$0.4m	$0.6m
2015/16	$3.5m	$8.6m	$3.6m	$0.5m	$2.4m

An important caveat is that this analysis doesn't account for the fact that historical generator behaviour may have been different had they been settled on a 5-minute basis. It is also a very simplistic calculation. Calculating the actual, historical difference between 30-minute demand side settlement and theoretical 5-minute settlement for the supply would be considerably more complex.[17]

The design of a mechanism to manage a settlement residue created by demand side optionality would need to consider:

- that the residue could be either a surplus or deficit for AEMO (i.e. the mechanism must be able to recover and allocate money in both directions);
- how recovery is to occur, including whether recovery can occur on a 30-minute basis;
- extent to which the residue provides an incentive to be metered on a 5-minute basis;
- whether the residue can be hedged; and
- if there needs to be a limit on the residue (such as in the case of negative *inter*-regional settlement residues) and what happens if the threshold is reached.

Some of these matters have been contemplated in the rule change request and during earlier consultation. Sun Metals proposed that the residue be recovered from customers that continue to be settled on a 30-minute basis. Stakeholders expressed differing views on this in submissions on the consultation paper.[18] Having considered these arguments, our view is that this approach would be consistent with the "causer pays" principle. The residue would be caused by those remaining on 30-minute settlement. It could be avoided by moving to 5-minute settlement (or by being metered on a 5-minute basis in the case of second tier retail customers).

An alternative approach considered was whether the new settlement residues should be combined with *intra*-regional settlement residues.[19] This would mean they would be

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17 A full analysis of the theoretical residue would need to consider loss factors, *inter*-regional flows and 5-minute payments to non-scheduled generators (which wouldn't be possible as in most cases 5-minute data is not available for these generators).

18 E.g. AER, ERM, IES, Origin, Stanwell, consultation paper submissions.

19 These are existing imbalances in the settlement transactions within each region resulting from differences between loss factors and actual losses on the transmission network, and metering errors

recovered from TNSPs, who would pass it through to consumers with other transmission charges. Those in favour of this approach noted that this would be consistent with the treatment of other residues, would reduce the implementation effort, and would allow for the relatively small settlement deficits to be absorbed in the generally positive *intra*-regional settlement residues. Those who opposed this approach did so on the basis that the i*ntra*-regional settlement residues serve a different purpose and should remain separate.

We have compared historical *intra*-regional residues with the indicative residue calculated above (the "5-minute residue"). In Table 4 below, the 5-minute residue due to optional 5-minute settlement for the demand side is expressed as a percentage of historical *intra*-regional residues (calculation: (5-minute residue/*intra*-regional residue) * 100). A negative value indicates that one residue is negative while the other is positive, while a positive value indicates that they are the same (e.g. both positive, or both negative).

Table 4: 5-minute residue expressed as % of *intra*-regional residue

Fin year	NSW	QLD	SA	TAS	VIC
2012/13	-2%	-4%	106%	-4%	-6%
2013/14	-1%	-4%	70%	-10%	-3%
2014/15	-9%	-7%	733%	-5%	-3%
2015/16	-20%	-18%	85%	-3%	-8%

The data shows that in the past four financial years:

- Annual *intra*-regional settlement residues have been negative in all jurisdictions aside from South Australia. This means that AEMO is in surplus from consumers paying *more* than is owed to generators. The indicative 5-minute residues are positive during the analysis period, corresponding with a deficit for AEMO from consumers paying *less* than is owed in generators.
- The 5-minute residues are much smaller than the *intra*-regional residues, usually corresponding to less than 10% of them. While the percentages for South Australia are large, the underlying residues are very small in absolute terms. The 733% result corresponds with a $0.4 million *intra*-regional residue and a $3 million 5-minute residue.
- Had the 5-minute residues been combined with the *intra*-regional residues this wouldn't have changed the direction of the *intra*-regional residue (e.g. turned a consumer surplus into a deficit, or vice versa). This is to say: it wouldn't have had a material impact on the operation of the *intra*-regional residue.

This analysis suggests that allowing any new settlement residue to merge with the existing *intra*-regional residues may be an acceptable approach. It would be cheaper to implement than a mechanism requiring the identification of customers who are settled

on a 30-minute basis. It would be no more complex than the existing arrangements. While it wouldn't provide any incentive for consumers that are metered on an accumulation or 30-minute basis to move to 5-minute metering, the incentive provided by a mechanism that *does* allocate the costs to these consumers would probably be very weak.

Further work is required to understand how *intra*-regional residues and the indicative 5-minute residues might change if 5-minute settlement is introduced, and whether this could lead to different outcome to those observed in the historical analysis above.

If a separate mechanism is required, an arrangement similar to FCAS "causer pays" may be most appropriate as it could be designed to recover the shortfall from 30-minute and accumulation metered end users that are consuming in the interval in which the shortfall occurred. This would be a cost-reflective arrangement, though the additional cost and complexity would need to be weighed up against the marginal benefit in comparison to using the existing *intra*-regional residues.

3.2. Settlement of the demand side

The settlement residues discussed above would be avoided if all demand side participants are also settled on a 5-minute basis. Implementing this would be a much larger task for industry than 5-minute supply side settlement as there are many more consumers than there are generators.

As noted above, Chapter 3 of the NER sets out the settlement arrangements for Market Participants, which includes Market Generators and Market Customers. Demand side participants may be eligible for the Market Customer category. A Market Customer is defined in the rules as "a Customer who has classified any of its loads as a market load and who is also registered by AEMO as a Market Customer". Customer is defined as "a person who engages in the activity of purchasing electricity supplied through a transmission or distribution system to a connection point". In practical terms, Market Customers are:

- retailers; and
- large energy users with single or multiple sites (e.g. Sun Metals).

In considering 5-minute demand side settlement, an important factor is whether or not end users have interval metering. These two customers groups (with and without interval metering) would be treated in different ways. Below we discuss a potential 5-minute settlement process for customers without interval meters and then for those that do. This is only to determine how much Market Customers (mostly retailers) need to pay. It is up to retailers to decide how they bill individual customers.

Settlement of customers without interval metering

A majority of residential and small business customers in all jurisdictions aside from Victoria have accumulation metering instead of interval metering. In the NEM there are over 6 million NMIs associated with accumulation meters, accounting for 65% of all NMIs. In energy terms though, accumulation metered customers account for 25-30% of energy consumed in each NEM region (except for Victoria, where this figure is closer to 4%).[20] As accumulation meters are typically only read only 3 months, AEMO uses the "settlement-by-difference" process so that the energy from accumulation meters can still be settled on a 30-minute basis.

Settlement-by-difference involves developing 30-minute resolution profiles which are used to allocate energy from accumulation meters to specific 30-minute periods. There is a separate profile for each distribution network region.

Profiles, called the Net System Load Profiles (NSLPs), are developed as follows:

1. Aggregating all energy flows from interval meters at the boundary of a distribution network region.
2. Subtracting from this aggregate all interval metered loads, or other loads as agreed in the settlement procedure for the NEM region (e.g. controlled loads and deemed unmetered loads).[21]

In each network region there is a first tier retailer that was the incumbent retailer prior to the introduction of full retail contestability.[22] Where other retailers have entered each market, they are classified as second tier retailers. Through this arrangement, a retailer can be classified as first tier in one region and second tier in another.

In terms of the accumulation metered customers, each second tier retailer is settled based on the aggregate load of its customers, shaped to the 30-minute NSLP, and 30-minute wholesale market prices. All remaining energy is assumed to have been served by the first tier retailer to interval metered customers and accumulation metered customers who are within its first-tier network boundary and are contracted to the first tier retailer. This energy is also shaped to the NSLP and settled against the 30-minute price. As the amount allocated to first tier retailers is determined on a net basis, they bear any risks associated with metering or profiling errors. While settlement statements are issued soon after each trading week, adjustments can be made up until 6 months later. Part of the reason for this is to accommodate the 3 monthly read cycle of accumulation meters (and Type 5 interval meters that are manually read).[23]

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20 Based on analysis of Net System Load Profiles and regional demand over the period December 2015 to July 2016.

21 AEMO, *Understanding load profiles published from MSATS*, August 2013.

22 Or, alternatively, a retailer that acquired the incumbent retailer after the introduction of FRC.

23 AEMO, *NEM Settlement Revisions Policy*, March 2013, p4.

Settling mass market customers on a 5-minute basis therefore requires either a 5-minute NSLP for each distribution network region, or for all of these customers to adopt 5-minute interval metering. A 5-minute NSLP could be developed using metered data from transmission connection points, as is the case with the existing 30-minute profiles. Some considerations in doing this would be:

- the ease with which wholesale metering at the transmission connection points can be reconfigured to provide 5-minute data (including addressing potential constraints on local data storage);[24]
- availability of SCADA data from transmission connection points and whether it is suitable for use in a 5-minute NSLP (similar considerations as in section 2.2 apply);
- the minimum proportion of connection points (or volume of energy flows) that needs to be represented in the 5-minute NSLP profile (e.g. 75%, 95%); and
- length of time to implement the 5-minute NSLP.

A "straw man" implementation option could involve a 5-minute NSLP based on 5-minute wholesale metered data where it is cost-effectively available within the implementation period, supplemented by SCADA data if necessary, for a majority subset of transmission connection points for a network region. A requirement for 5-minute Chapter 7-compliant metering could be applied after some years (e.g. 5 or 10 years), to allow for wholesale meters to be gradually reconfigured or replaced.

Alternatively, the 5-minute NSLP could be based on some other data source. One option is profiling the 30-minute NSLP using regional consumption (i.e. regional generation plus net imports). Whether this could be based on 5-minute metered data would depend on whether 5-minute generator settlements are based on metered or SCADA data (as discussed in section 2.2). Metering at regional boundaries would also need to be considered. A second option is profiling the 30-minute NSLP using the load profile from a subset of customers that have 5-minute metering. This approach is currently used for Controlled Load Profiles in several NEM regions.

We welcome stakeholder feedback on the feasibility of these options. We note that as interval metering becomes increasingly prevalent, the volume of energy transactions that are derived using the NSLP will be diminished. A relatively cheap solution for dealing with accumulation metered customers and the NSLP under 5-minute settlement would be desirable.

[24] Modifications to wholesale metering may in some cases be more expensive than changes to generation meters due to complicated access arrangements, outages and/or specialised cabling (e.g. optical fibre).

Settlement for customers with interval metering

As explained above, the NSLP used to settle accumulation metered customers is calculated by subtracting interval metered energy from the total energy flows into a distribution network region. For there to be a 5-minute NSLP, it follows that 5-minute data would be required for all loads that have interval metering. The same considerations as in section 2.2 apply, but on a much larger scale. Table 2 in section 2.2 provides an indication of the number of NMIs that are involved (noting that there can be multiple meters at each NMI). In addition to the NMIs in Table 2, there are over 3 million Type 5 meters, most of which are in Victoria.[25]

5-minute data would also be required to settle the Market Customers (specifically, second-tier retailers) that serve interval metered customers. As mentioned above, irrespective of whether 30-minute or 5-minute data is collected, it is up to retailers to decide how they bill their customers. Interval metered customers could be either metered directly or profiled from existing 30-minute or 15-minute readings. Profiling could be based on aggregate or individual transmission point flows, regional consumption, deemed profiles, or some other mechanism. The considerations are similar to those outlined above. The arrangements for settling interval metered customers on a 5-minute basis impacts on the NSLP (and settlement for accumulation metered customers) through the settlement-by-difference process.

As yet it is unclear whether the Victorian Advanced Metering Infrastructure is capable of facilitating 5-minute settlement of those customers. However, the meters used for this roll-out may have enough local storage capacity depending on how many data streams are required. For example, the Landis+Gyr E350 can store 198 days of 10-minute resolution data for 1 set and 4 channels, suggesting that storing more than 35-days' worth of 5-minute resolution data would be possible.[26]

A decision would need to be made about whether large energy users that are Market Customers should be eligible for profiling. If 5-minute settlement is compulsory for all Market Participants, then Market Customers would be settled on this basis and would have to provide either SCADA or 5-minute metering data (depending on design choices discussed elsewhere in this paper). Large users that are contracted through retailers wouldn't face the same obligation under the rules, but it may still be desirable for them to be metered on a 5-minute basis.

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25 The Type 5 classification is for Manually Read Interval Meters. In Victoria, there is a jurisdictional derogation to the NER which allows the Type 4 meters to be classified as Type 5. This will end on 1 December 2017, at which point those 2.6+ million meters will have to be classified as Type 4 if they are remotely read.

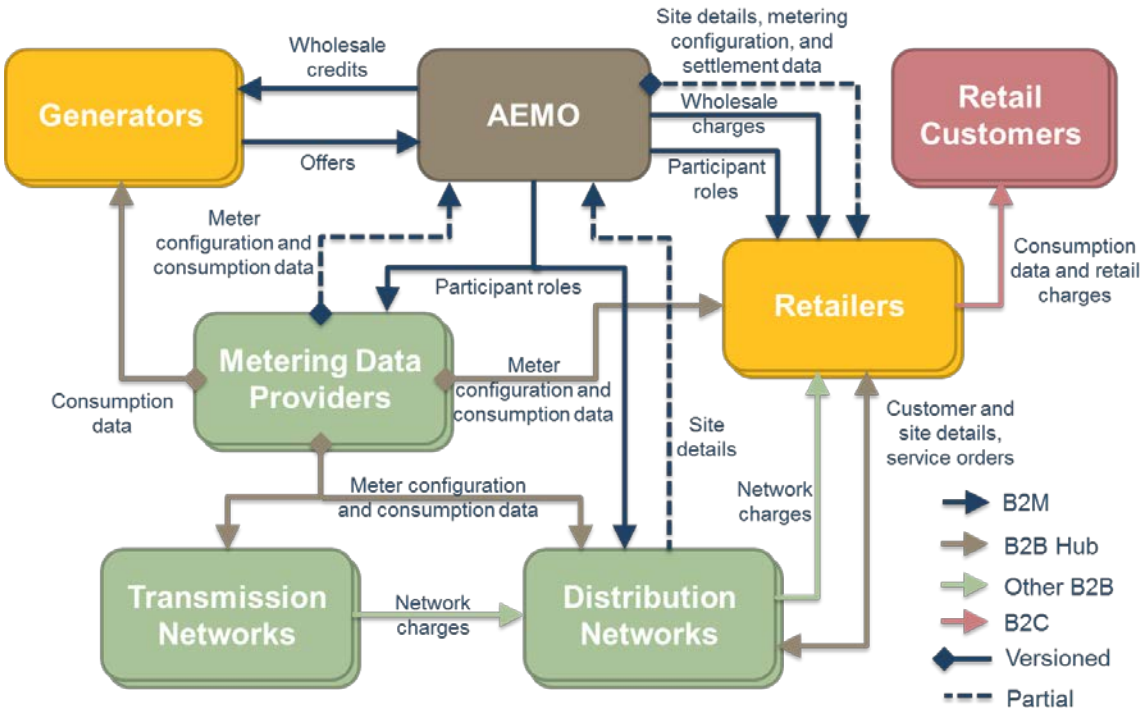
26 http://www.landisgyr.com/webfoo/wp-content/uploads/2014/06/E350-Brochure.pdf

3.3. System changes

An area where major changes may be required to implement 5-minute settlement is the information systems and processes of market participants and the market operator. The full scale of these changes would depend on the design and implementation options discussed in this paper. At this stage we are interested in hearing from stakeholders about the relative impact of the design and implementation options on their systems and processes (i.e. if certain choices would lead to orders of magnitude differences in the cost of system changes). Once the most feasible implementation options have been identified, we will seek more detailed estimates of costs from those who would be affected.

If 5-minute metering data is used, there would be costs associated with systems that handle metering data, such as AEMO's MSATS system, Meter Data Providers' systems, and the settlement and billing systems of market participants. The existing metering data file formats (NEM12 and NEM13) have a field for the resolution of the data that accepts intervals of 1, 5, 10, 15 and 30 minutes, but presently only 15 and 30-minute data is widely used.[27] Figure 1 below shows the information flows between NEM participants. "Versioned" refers to instances where data can be revised when more accurate data becomes available, while "Partial" are information flows that involve a subset of all NMIs.

Figure 1: Electricity market information flows (Source: AEMO)



27 AEMO, *Meter Data File Format Specification NEM12 & NEM13*, 14 May 2014, p15.

In considering potential changes to systems, we note that:

- Participants may have other reasons for upgrading their system that are unrelated to 5-minute settlement, such as periodic improvements or in response to technological change. To the extent that these factors apply, it would be inaccurate to include the full cost of these changes in the AEMC's assessment of the rule change.
- Where products and services are supplied by third-party providers, the costs of adapting to 5-minute settlement would be spread across the customer base of these providers. The AEMC will seek to account for these synergies in assessing the potential cost of system changes.
- There may be synergies between the changes necessary to implement 5-minute settlement and other upgrades necessitated by other regulatory processes and operational changes by AEMO.

The following sections provide further commentary in relation to specific stakeholder categories.

AEMO

AEMO has prepared a separate paper that discusses implementation impacts associated with different design options. AEMO's paper has been provided to the Working Group at the same time at this paper.

MDPs, TNSPs and DNSPs

Metering Data Providers (MDPs) provide metering solutions to retailers, collect metering data, undertake checking and cleaning of metering data, store data and provide metering data to customers. No changes would be required by MDPs if 5-minute settlement is implemented for the supply side only using SCADA profiling. If 5-minute metering is used then MDPs would be required to process increased volumes of data. They may have to make changes to algorithms that check and clean the data (e.g. learning algorithms that fill gaps in the data). They would face higher data storage costs.

Transmission and distribution network services providers (TNSPs and DNSPs) would be affected in implementation scenarios involving 5-minute settlement for the demand side using metering data. Metering data is used in settlement and billing processes to calculate network changes that are passed on to retailers. These systems currently accommodate 30-minute and 15-minute data, with the later used for calculating demand charges for larger consumers. Changes would presumably be required to accommodate 5-minute data. NSPs may seek to calculate demand charges on a 5-minute basis, which would be more cost reflective.

The other way in which TNSPs and DNSPs could be affected is in relation to transmission connection point metering, which they own. 30-minute data from these locations is used to calculate the NSLP for the settlement of accumulation metered consumers. In scenarios involving compulsory 5-minute settlement for the demand side, it may be desirable to have a 5-minute NSLP (as discussed in section 3.2). If implemented with 5-minute data from the transmission connection points, then changes may be required to SCADA or metering at these locations.

Retailers and generators

In submissions on the consultation paper, retailers and generators were of the view that system changes, particularly on the retail side, would be costly and extensive. We are thinking about these systems in terms of the following categories:

- settlement and billing;
- energy trading and risk management (ETRM); and
- other internal processes (e.g. modelling, forecasting, sales and marketing)

Settlement and billing systems may need to be adapted to accept more granular data from MDPs (though using the existing data file format). For example, changes may be required to accommodate customers that are supplied under spot price pass-through contracts, and to the processes that reconcile settlement information provided by AEMO.

ETRM packages are used by generators, retailers and traders when buying and selling energy in the physical and financial markets. They typically include features for bidding, forecasting, valuing and entering into contracts (i.e. deal capture) and analysing risk. ETRM software may need to be adapted under 5-minute settlement to accommodate 5-minute forecasting, contracts that settle on a 5-minute basis and changes to bidding (if there is a change to the bidding interval - see section 3.4).

We understand from our discussions with stakeholder that the factors contributing to the costs of system changes include:

- complexity due to legacy factors such as acquisitions and past or present government ownership;
- age of systems;
- level of outsourcing versus in-house solutions (and whether service providers are local or based offshore)
- whether systems are bespoke or "off the shelf"; and
- extent of system fragmentation.

Projects to change systems that are more complex, older and more fragmented are expected to involve higher levels of cost and risk. However, there may be other

benefits in upgrading these systems to accommodate 5-minute settlement, such as higher reliability, less errors, or a better user experience. Outsourced systems may prove cheaper to change if the same change applies across the market and the product is used by multiple participants. In the case of US-based systems providers, these packages may already cater for 5-minute settlement as some US electricity markets are already settled on a 5-minute basis.[28]

Large energy users

The potential impacts for large energy users depend on the key design choices around demand side optionality and whether SCADA or metering data is used for 5-minute settlement. If 5-minute settlement is optional, then only those that opt-in would be required to make changes. These changes may relate to metering and the systems that monitor the spot price. Changes to control systems may be considered for customers that engage in demand response if they desire a greater degree of sophistication and/or responsiveness.

If 5-minute settlement is compulsory at the Market Customer level, then Market Customers would be required to make changes to metering, spot price monitoring software and settlement systems. Large energy users on retail contracts could be unaffected from a systems perspective, though metering changes may be required so that 5-minute data can be used in settlement of the Market Customer that they have contracted with. Retailers may seek to meter customers on a 5-minute basis and offer spot pass-through arrangements that reference the 5-minute price.

3.4. Other potential changes

In this section we comment on some other changes that have been suggested by stakeholders during this rule change project. These are potential changes to the bidding resolution and the application and cost recovery of FCAS charges. These items are still subject to an assessment of whether they relate to the issues raised in Sun Metals' rule change request and are within scope of a potential rule.

Bidding resolution

The existing rules specify that scheduled generators must submit generation dispatch offers for each trading interval (i.e. each 30-minute period).[29] The price and dispatch levels that are offered are uniform within each trading interval. Generators can submit rebids up until the time of dispatch that vary the dispatch quantities in each price band

28 The Californian, New York and Southwest Power Pool markets dispatch and settlement their real-time markets on a 5-minute basis.

29 NER, rules 3.8.2(a) and 3.8.6(a).

of the bid.[30] Since the rebid varies the original dispatch offer, it is not possible to rebid for an individual 5-minute period as the rebid applies for a whole trading interval. The exception to this is when a rebid is submitted for a trading interval that has already started. In this case, the rebid only affects the remaining dispatch intervals of that half hour. [31]

Intuitively, there would be alignment between the intervals for bidding and dispatch as they are both operational processes. That this is currently not the case suggests that 5-minute settlement could be implemented without changing the bidding interval.

We are interested in stakeholder's views in whether 5-minute resolution offers (and rebids) would be a necessary, complementary change if 5-minute settlement is introduced. Participants could use the 5-minute resolution during their initial offers and during rebidding. Initial offers must be submitted before 12.30pm (i.e. between 15.5 and 39.5 hours before the trading interval to which the offer relates). Considering how far in advance initial offers are submitted, the 5-minute granularly may not be all that useful for initial offers. In rebidding, though, the 5-minute granularly would allow for a rebid to be targeted at a specific 5-minute period rather than applying for several 5-minute periods in a half hour.

In considering a potential change to the bidding interval, if judged to be within the scope of the rule change request, we would consider:

- whether 5-minute offers and rebids would be an improvement in comparison to a) the status quo, and b) in comparison to 5-minute settlement with 30-minute offers;
- the likely costs to participants and AEMO to provide and process more granular offers, (i.e. 288 price-volume combinations for a day, as opposed to 48 at present); and
- other changes to bidding that may be scheduled to occur.

On the first of these points, 5-minute bidding would better accommodate energy-limited supply sources and generators with complex ramping characteristics. Peaking generators have historically been able to generate for more than half an hour, but may in some cases face challenges in expressing physical limits in 30-minute bids. In the future there may be more supply sources that will provide energy for less than 30-minutes at a time (e.g. batteries). This may present a compliance issue if energy-limited supply sources make 30-minute bids that they are physically incapable of honouring.

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30 NER, rule 3.8.22. Among other things, generators can vary their available capacity. This is defined as: "in relation to a specific price band, the MW capacity within that price band available for dispatch (i.e. availability at each price band)".

31 Technically, the rebid changes the offer for the whole trading day, but settlement is based on the offer or rebid that was accepted by the dispatch engine.

There may be other ways of addressing this while maintaining 30-minute offers. For example, the daily energy limit field of offers could be repurposed to specify energy limits over a shorter period, or a new half hourly energy limit field could be introduced.

FCAS "causer pays" regime

AEMO uses frequency control ancillary services (FCAS) to maintain the frequency of the power system. There are two categories of FCAS: regulating and contingency. Regulating FCAS is continually used to correct minor imbalances between supply and demand. Contingency FCAS is used to rebalance the system following a contingency event, such as the loss of a generating unit or major load.

The NEM dispatch assumes that loads and generating units ramp in a straight line from one 5-minute MW level to the next. Regulation FCAS is used to manage variations from the assumed, linear trajectories. The costs of providing regulation FCAS are recovered from the participants that are judged to have created the need for regulation FCAS by deviating from the linear trajectory.[32] This arrangement is the so-called FCAS "causer pays" regime.

A nuance of the causer pays methodology is that costs are not allocated based on deviations in each 4-second or 5-minute period. Rather, causer pays is based on "contribution factors" calculated over the preceding 28-day period. Deviations are calculated on a 4-second basis and then averaged over each 5-minute period to generate 5-minute "performance factors". These are summed over a 28-day period to calculate the contribution factor to be applied to allocate regulation FCAS costs in the upcoming 28-day period.[33]

In submissions on the consultation paper, stakeholders raised concerns that 5-minute settlement would provide a greater incentive to deviate from dispatch targets and from the linear ramp. For example, in periods of high prices, generators that can ramp quicker than the assumed linear ramp may choose to do so to maximise their output during that 5-minute period. It has been suggested that there could be "piling in" within a 5-minute period, driving up regulation FCAS costs and destabilising the system.

As FCAS payments are calculated using the ex post contribution factor, there is no direct link between a participant's decision to deviate from a dispatch target or the linear ramp assumption, and cost allocation under "causer pays" for the corresponding

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32 All market generating units, loads and small generating units can be included, subject to their being appropriate metering. In practice, this means that non-scheduled generators and non-scheduled loads are generally not included in the process. However, if 5-minute settlement is introduced, non-scheduled generators would be required to provide 5-minute data, which could be used to calculate FCAS causer pays contribution factors.

33 AEMO, *Causer Pays Procedure*, 15 December 2013.

period. This suggests that the "causer pays" methodology needs to be more specific than the existing contribution factors so that participants can decide whether it is worth deviating from linear ramp assumption. Deviating from dispatch targets (as opposed to the assumed linear ramp) is a compliance issue that is dealt with by the AER.

We consider this issue worth investigating, however it would need to be dealt with via a separate rule change.

4. Transition process

Given the changes that would need to occur if the Commission makes a rule to implement 5-minute settlement, an appropriate transition path would be required. The process may be more manageable, and the transition costs for market participants lower, if there was a transition period between the AEMC's final decision and the rule coming into effect. The length of this period would depend on the time required to make changes to systems and process, and to transition contractual arrangements. In this section, we first discuss contract market impacts and then the potential length of a transition period.

4.1. Contract market

External to the NEM, market participants and intermediaries enter into contractual arrangements to manage the risks associated with volatile wholesale prices. The main markets for this trading are the exchanged-traded market (operated by the Australian Stock Exchange (ASX)) and the over-the-counter (OTC) derivatives market. Trading also takes place via Power Purchase Agreements (PPAs) and the Settlement Residue Auction (SRA) operated by AEMO.

We are interested in understanding the impact that the rule change would have on the financial markets because:

- physical market changes resulting from the rule change will manifest as changes in the financial markets (which is to say: efficiency gains in the physical market will be allocated between participants *via* the financial markets);
- changes in the financial markets will impact on end users via retail contracts; and
- the Commission's decisions must have regard to the long term interests of consumers of electricity.

In this section we discuss how different types of contracts might be affected by a move to 5-minute settlement, and how open positions could be transitioned. With the exception of ASX trades, the financial markets are generally opaque to non-participants. As such, we welcome information from stakeholders to improve our understanding of the potential impacts in this area.

Impact on different types of contracts

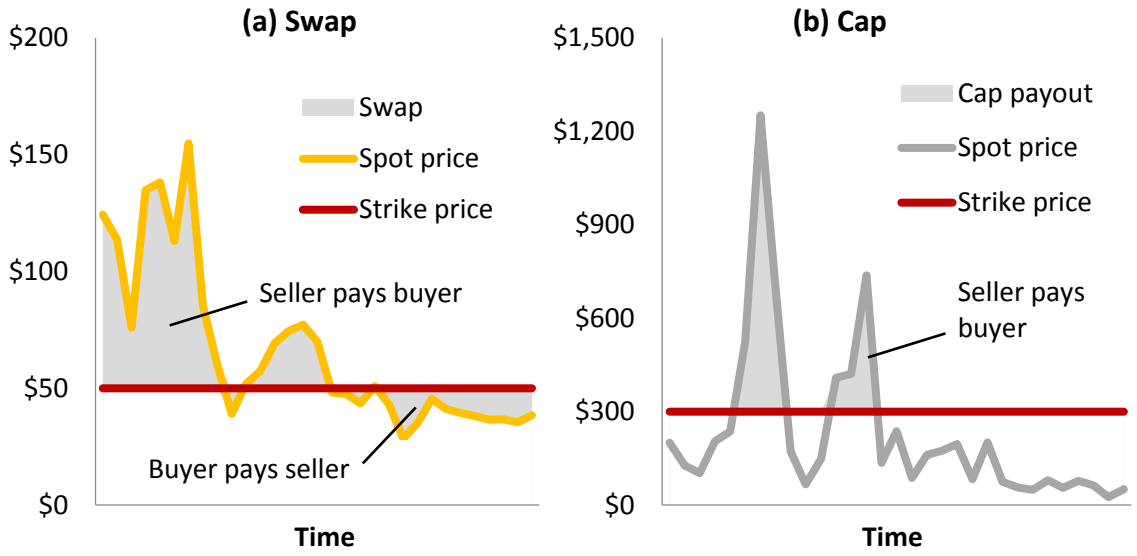
The most common types of electricity derivatives are "swaps" (referred to as "futures" in ASX trades) and "caps". In 2014/15, swaps accounted for 79% of trading in electricity derivatives while caps account for 16% of the volume.[34] The remaining trading volume consists of different types of derivatives, such as "swaptions", "floors", "collars", and Asian options.

34 AFMA, *2015 Australia Financial Markets Report*, p48.

These contracts operate as follows:

- Swap: two parties swap a fixed set of cash flows (i.e. a "strike price") for a floating set of cash flows (i.e. the spot price). In doing so, both parties remove their spot price exposure for the period and MW quantity of the contract. Swaps can be tailored to only apply in specific circumstances (e.g. an option on a swap, or swaption), follow a specified load shape, and have varying levels of firmness. Figure 3(a) below provides an illustrative example.
- Cap: for a defined quantity, one party pays a fixed premium in return for receiving the difference between the spot price and a strike price (usually $300/MWh). The transaction only applies if the spot price is greater than the strike price. For the volume of the contract, the buyer's price exposure is capped at the strike price. Figure 3(b) provides an example.
- Floor: opposite of a cap (i.e. the transaction applies if the spot price is *less* than the strike price.
- Collar: a cap and floor transacted at the same time. One party buys the cap (and sells the floor), and the other party buys the floor (and sells the cap). The strike prices of the cap and the floor and be chosen so that there is no need for a premium.
- Asian options: caps or floors where the payoff is based the average spot price over the period of the contract (such as a quarter), rather than half hourly spot prices.

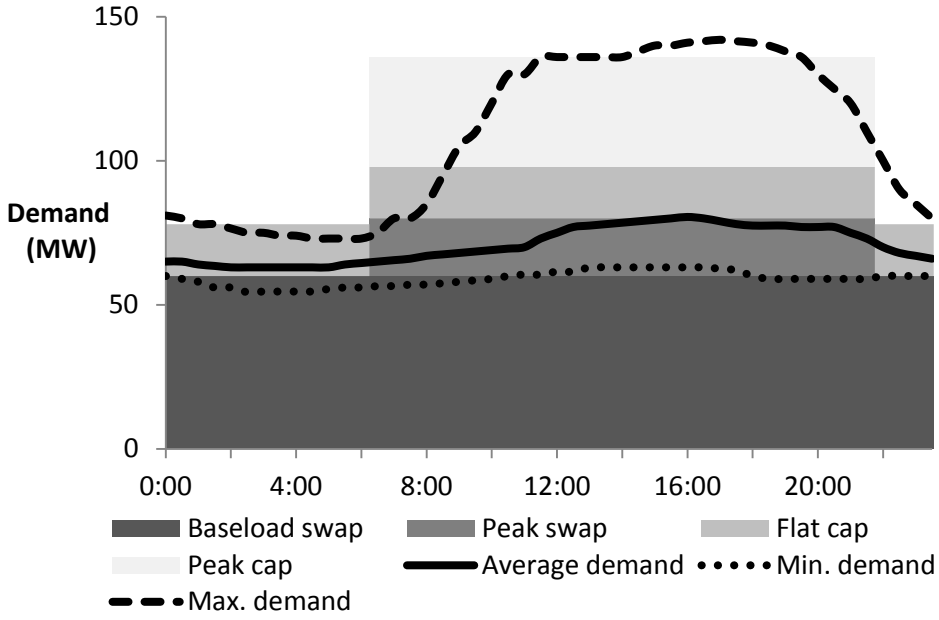
Figure 2: Illustrative example of swap and cap contracts



The following discussion focuses on swaps and half hourly caps as they represent the bulk of traded energy. Figure 4 below is an illustrative example of managing a variable load profile with swaps and caps. Peak swaps and caps are contracts that are only active during a defined peak period (such as 7am to 10pm weekdays). The relatively

flat minimum and average loads are hedged with swaps. Caps are used to hedge the maximum load scenario as this level of contract cover is not required on a regular basis.

Figure 3: Managing a variable load with swaps and caps



A key point of difference between swaps and caps is how they are priced. The forward curve for swaps reflects the market's expectation of the average spot price over the period of the product. Moving to 5-minute settlement is expected to have a limited impact on swaps as it is unlikely to materially change average spot prices in the short term. The ability to enter into basic swaps should also be unaffected by 5-minute settlement that is optional for the demand side, since these contracts are for a fixed volumes of energy (and discrepancies between 30-minute and 5-minute settlement only occur when generation or consumption varies *within* a half hour).

Caps involve the payment of a premium by the buyer that is based on the expected payout from half hours above the spike price during the contract period. The premium can be thought of as a capacity payment: the seller is compensated irrespective of whether it is required to pay out on the contract. However, in pricing the contract the seller will estimate how much it will likely be required to pay out. A key input to determine the premium is therefore the expected spot price volatility exceeding the strike price. Moving to 5-minute settlement is likely to change spot price volatility and therefore impact on trading in caps and strategies that involve cap contracts.

The price and availability of caps are a function of:

- expectations of price volatility exceeding the spike price (i.e. $300/MWh); and

- the ability of cap sellers to manage risk (i.e. by recovering the money payable under the contract in the spot money).

At the first Working Group meeting, there were differing views on the impact of 5-minute settlement would have on spot price volatility. Some stakeholders are of the view that volatility would increase because the current 30-minute averaging smooths out the 5-minute price. This is to say that the 5-minute volatility currently observed would be transferred through to 5-minute settlement. There could also be additional volatility due to generator ramp rate and other physical constraints affecting the ability of some generators to respond to 5-minute prices.

A contrasting view is that the existing volatility *within* the half hour is largely a function of the 30-minute averaging. For example, under 5-minute settlement there would no longer be situations of a $14,000/MWh price spike followed by zero or negative prices as generators ramp up to maximise their energy over the half hour (i.e. "piling in"). In the absence of this behaviour, there should be less volatility in 5-minute settlement.

On balance, there may be less artificial volatility due to scenarios like the one described above, but also new volatility reflecting physical constraints (e.g. ramp rates). In a comparison between 30-minute volatility under 30-minute settlement and 5-minute volatility under 5-minute settlement, it is unclear whether volatility would be greater. Regardless, the new volatility should be a better reflection of supply and demand fundamentals, and therefore a better basis for participants' operational and investment decisions. Over time, the adaptation of existing assets and entry of faster response technologies may result in less volatility and flatter spot market prices.

The ability of cap sellers to manage risk depends on their ability to be generating during high price periods. Existing strategies often involve committing units when a 5-minute price spikes occurs, but due to the time to synchronise, energy is not provided to the market until 5 to 15-minutes after the end of the 5-minute price spike. Unless a price spike is sustained for multiple 5-minute periods, the ability of existing peaking generators to sell caps would be diminished if they continue to operate in this manner.

In the first Working Paper we discussed different ways in which generators might be able to respond faster and thereby increase their ability "capture" high spot prices. One option is being more responsive to price forecasts and ramping up in anticipation of high prices. Units could be run more often between short run marginal cost (~$150/MWh for an OCGT) and $300/MWh in anticipation of high prices. Changed operation could be complemented by investments in faster demand response or storage technologies.

A further consideration is whether 5-minute settlement is optional for the demand side. As mentioned in section 2, if demand side participants continue to be settled on a 30-minute basis, there could be situations of a 30-minute settled load seeking to

contract with a 5-minute settled generator. One party would be exposed to "basis risk" from being settled by the market on a different basis to the reference price of the contract. This may serve as a disincentive for entering into cap contracts.

We are interested in stakeholders' views on whether we have correctly identified the impacts for different types of contracts. We welcome suggestions of further analysis that we should consider in this area.

Potential transition process

If the transition period is sufficiently long, then the bulk of open contracts will be able to run their course. For those that endure beyond the transition period, it may be desirable for counterparties to:

- change provisions relating to the reference price;
- change the strike price to reflect a changed risk profile; or
- terminate the contract without penalty if one or both parties are no longer able to cost-effectively manage their obligations under the contract.

The process for doing this would vary depending on whether contracts are exchange-traded via the ASX, OTC trades, PPAs or SRA positions. Some relevant features of these trading arrangements are summarised in the following table.

Table 5: Comparison of different trading arrangements

Market	Legal framework	Length of forward trading	Ability to renegotiate open position?
ASX	ASX rules and policies	Up to 4 years ahead	No
OTC	ISDA	Unlimited	Possible, if standard conventions adopted
PPAs	Contract law	Unlimited	Possible, if included in contract
SRAs	NEL, NER, AEMO Procedures	Up to 3 years ahead	No, but can be terminated

ASX products can be traded up to 4 years ahead, though our analysis has found that most trading occurs with one year of the delivery period (see section 4.2). A defining feature of ASX trading is that there are no change of law or regulatory change provisions associated with the trades. There are, however, actions that the market operator could take to transition contracts. For example, the market operator could create 5-minute derivatives so that participants could sell out of their existing 30-

minute-based contracts and buy the corresponding 5-minute product. Of course, the need to trade out of 30-minute positions would be avoided by having a transition period that is more than 4 years.

OTC trades are for the most part opaque to non-parties, however some observations can be made using the standard conventions used by trading counter-parties. They are specified by the International Swaps and Derivatives Association (ISDA) framework.[35]

The ISDA conventions specify a "Commodity Reference Price" for a trade, such as the half hourly NEM spot price. Trades can include provisions for "Market Disruption Events", such as "Material Change in Formula". If participants have used the common definitions, it appears that this type of disruption event would apply if the NEM physical market moved to 5-minutes settlement. If a disruption event is established then "Disruption Fallbacks" can be specified, such as a "Fallback Reference Price", a "Negotiated Fallback", or "No Fault Termination". The "Negotiated Fallback" specifies that counter parties will negotiate in good faith on the Relevant Price.

We would like to know from stakeholders how common it is for these provisions for "Market Disruption Events" and "Disruption Fallbacks" to be included in OTC trades. Under the full, standard ISDA conventions, it appears that there is a robust framework to deal with a changed reference price. Where these conventions are not followed, parties appear to have made an active decision about how the arrangement will be affected by disruptions.

PPAs are a contract whereby a party agrees to buy a generator's output at the strike price. Historically, PPA contracts have been bespoke, though they are now widely used in wind and solar applications and may have become more standardised. While PPAs can be set up to have the same financial outcome as a swap, they are legally quite different to OTC trades and don't follow the ISDA conventions. We understand that PPA contracts usually have change of law or regulatory change provisions. [36] However, as each contract can potentially be different it is unknown if this is always the case. To the extent that these contracts operate like a swap, it may not be necessary to make changes to these contracts, other than to the provisions relating to the reference price.

In terms of SRAs, AEMO operates four auctions each year via which SRA units are sold for each of the twelve quarters covering the upcoming 3 year period. The units are a part entitlement to the *inter*-regional settlement residues that arise due to price separation between NEM regions. Each SRA auction involves one-twelfth of the units for each quarter, e.g. on 15 December 2016 it will be possible to bid on units from the twelfth tranche of units for Q1 2017 through to the first tranche for Q4 2019. What this

35 https://www.db.com/company/en/media/Supplement-to-Sub-Annex-A-to-the-2005-ISDA-Commodity-Definitions.pdf

36 For example, the draft Deed of Entitlement between the ACT Government and successful participants in its renewable energy reverse auctions includes in its definition of a "change of law": *"a change to the National Electricity Law or the National Electricity Rules"*.

means is that the volume of purchased SRA units diminishes over the forward trading period, in a similar but potentially more structured way to trading in ASX energy products.

Under the SRA Auction Participation Agreement, a participant can terminate the agreement if there is a change in the way in which the settlement residue is calculated. The participant would also be eligible for a refund on the purchase price.[37] However, moving to 5-minute settlement may increase the value of SRA units that have already been purchased by causing larger *inter*-regional residues.[38] This would provide a disincentive to terminate an existing SRA agreement.

This consideration of the different trading arrangements shows that there are avenues potentially available to parties to vary those contracts that endure beyond a transition period. Our preliminary view is that transitioning to 5-minute settlement, from a contract market perspective, would be a large, but not insurmountable, undertaking for NEM and financial market stakeholders. A key consideration is whether the change would result in undesirable contracting outcomes if 5-minute settlement is optional for demand side participants.

4.2. Length of transition period

Under the NEL, the AEMC can make a rule that doesn't come into effect straight away. Using this discretion, a transition period of some years could be provided if the Commission makes a rule to implement 5-minute settlement. The length of a transition period would be a function of:

- time for industry to update systems and processes;
- time to transition contractual arrangements; and
- any net benefit that may be achieved by having 5-minute settlement sooner.

The time required to update systems and processes would depend on the way in which 5-minute settlement is implemented. This will be clearer once the most feasible design and implementation options have been identified. We expect this to happen after the second Working Group meeting and further discussions with stakeholders.

In the previous section, we noted that there are limits on the length of forward trading of ASX products and SRA units. As it happens, there is also a greater level of transparency around these trades than for OTC and PPA trades. We have analysed ASX data to observe the distribution of historical traded volumes. For delivery periods in the past 5 years, the volume of baseload quarterly swaps traded within one year of, or during, the delivery period has been between 60% and 85% of the total volume traded for each product. The result is similar across all four traded regions.

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37 AEMO, *Auction Participation Agreement*, clauses 13.5 and 13.6.

38 Liquid Capital, consultation paper submission; and AEMO consultation paper submission.

The following table shows a snapshot of the data for the past two years.

Table 6: Percentage of volume traded at various times before delivery

Region	Product	4-3 yrs	3-2 yrs	2-1 yrs	<1 yr
NSW	Q4 2014	0%	0%	20%	80%
NSW	Q1 2015	0%	1%	16%	82%
NSW	Q2 2015	0%	4%	20%	76%
NSW	Q3 2015	0%	0%	13%	86%
NSW	Q4 2015	0%	0%	22%	78%
NSW	Q1 2016	0%	0%	20%	80%
NSW	Q2 2016	0%	1%	25%	75%
NSW	Q3 2016	0%	0%	23%	77%
Vic	Q4 2014	0%	3%	12%	84%
Vic	Q1 2015	0%	0%	12%	88%
Vic	Q2 2015	0%	0%	20%	80%
Vic	Q3 2015	0%	1%	16%	83%
Vic	Q4 2015	0%	1%	23%	75%
Vic	Q1 2016	0%	0%	20%	80%
Vic	Q2 2016	0%	1%	24%	75%
Vic	Q3 2016	0%	0%	16%	84%
Qld	Q4 2014	0%	1%	23%	72%
Qld	Q1 2015	0%	1%	21%	79%
Qld	Q2 2015	0%	4%	16%	81%
Qld	Q3 2015	0%	0%	8%	92%
Qld	Q4 2015	0%	1%	16%	83%
Qld	Q1 2016	0%	2%	18%	80%
Qld	Q2 2016	0%	2%	26%	71%
Qld	Q3 2016	0%	0%	24%	76%
SA	Q4 2014	0%	0%	8%	92%
SA	Q1 2015	0%	3%	15%	82%
SA	Q2 2015	0%	2%	29%	69%
SA	Q3 2015	0%	1%	32%	67%
SA	Q4 2015	0%	1%	33%	66%
SA	Q1 2016	0%	4%	19%	77%
SA	Q2 2016	0%	6%	14%	80%
SA	Q3 2016	0%	1%	14%	84%

This analysis suggests that if 5-minute settlement is implemented with a transition period of 2 years, close to all the open positions in ASX baseload quarterly swaps would have passed the delivery period of these contracts. We have received anecdotal evidence to suggest that there is a similar trend in the case of OTC trading. We also

note AFMA reporting of ASX and OTC trading was that in 2014/15 - the most recent reporting year - 94.8% of the volume of swaps, and 97.5% of cap volume, was for tenors equal to or less than 12 months. While this doesn't indicate the timing of the delivery period, it does suggest that the bulk of trading activities occurs close to the delivery period.

Notwithstanding this, we acknowledge that there are some long-dated contracts in the market that have tenors of up to 10 years. We understand that participants typically enter such contracts to underpin large capital investments such as in power generation infrastructure. We would like to understand the prevalence and type (e.g. swap, cap, or other) of these long-dated contracts so to assess how they could be accommodated in a transition to 5-minute settlement.

Our analysis to date suggests that a period of several years could be appropriate to transition contracts to 5-minute settlement, but changes to IT systems and metering may require more time.

5. Next steps

The AEMC's standard rule change process involves 6 months from publishing a consultation paper to publishing a final determination. This rule change project has been extended under s. 107 of the NEL to allow for greater stakeholder engagement, including the Working Group and staff working papers.

Formally, the AEMC is now required to publish a draft determination by 30 March 2017, which corresponds with a final determination by 22 June 2017. Some stakeholders have suggested that we should undertake another formal round of consultation (e.g. a directions paper) before publishing the draft determination. A directions paper would allow stakeholder to lodge submissions on the Commission's preliminary position on the rule proposal and for us to seek further information on specific issues.

An additional round of consultation would require a further extension of the project in the order of 2-3 months. An indicative timeline for this is provided below. We welcome views on whether stakeholders would value another formal round of consultation and whether it is worth extending the project to do this.

Milestone	Current timeline	Further extension timeline
Second Working Group Meeting	1 Dec 2016	1 Dec 2016
Public forum (TBC)	Feb 2017	n/a
Publish directions paper	n/a	30 March 2017
Public forum (TBC)	n/a	April 2017
Submissions due on directions paper	n/a	11 May 2017
Publish draft determination	30 March 2017	6 July 2017
Submissions due on draft determination	11 May 2017	17 August 2017
Final determination	22 June 2017	28 September 2017