Australian Energy Market Commission

RULE CHANGE

DIRECTIONS PAPER

Five Minute Settlement

11 April 2017

Reference: ERC0201
Directions Paper

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Reference: ERC0201

Citation

AEMC, *Five Minute Settlement*, directions paper, 11 April 2017, Sydney.

About the AEMC

The AEMC reports to the Council of Australian Governments (COAG) through the COAG Energy Council. We have two functions. We make and amend the national electricity, gas and energy retail rules and conduct independent reviews for the COAG Energy Council.

Summary

The national electricity market (NEM) is undergoing a significant transition. Electricity generation in Australia (and internationally) is increasingly being provided by lower emissions, intermittent technologies. This trend is likely to continue in the future. The adoption of more intermittent generation such as wind and solar, combined with the need to replace existing large-scale synchronous generation, means there is an increasingly important role played by flexible generation to support intermittent generation. Currently, supply-side flexibility in the NEM is provided by hydro, gas peaking, and diesel fuel generators.

The generation mix will change further as technology advancements improve the economics of faster and more flexible demand and supply solutions. Given the change underway, it is increasingly important that the NEM market design provides the right price signals, as this will affect the incentives for the efficient use of generation assets, the efficient consumption of electricity, and efficient investment in generation and demand-side technologies.

It is in this context that the Australian Energy Market Commission (the AEMC or Commission) is considering the rule change proposed to implement five minute settlement. The Commission is looking to assess which market design will provide the best outcomes for customers, while affording generators the opportunity to earn sufficient revenue from providing energy and ancillary services that maintain the security of the power system.

Overview of the rule change request and this paper

In December 2015, Sun Metals Corporation Pty Ltd (Sun Metals) submitted a rule change request to the AEMC. Sun Metals proposed that the time interval for financial settlement in the wholesale electricity market be reduced from the current 30 minutes to five minutes. Such a change would align financial settlement with the five minute timeframe for dispatch. The proposal involves:

- compulsory five minute settlement for generators, scheduled loads and market interconnectors
- a choice of either a five or 30 minute settlement interval for retailers and large consumers.

Given the complexity and broader context of the rule change request, stakeholders requested that the Commission undertake an additional round of consultation before making a draft decision. They identified this was a significant change for the sector and understanding the Commission's initial implementation preferences was crucial, as it could materially affect the realised costs and benefits.

This directions paper has been prepared in response to this feedback. It provides the Commission's initial position on the rule change request and views on the design and implementation of five minute settlement. It seeks feedback from stakeholders on the

immediate and future costs and benefits of five minute settlement to inform the Commission's draft decision on the rule change request.

Benefits of five minute settlement

A physical requirement of power systems is that demand and supply must be balanced in real-time. Ideally, as demand and supply vary continuously, the price signal would also vary in real-time. A market where the price provides signals and incentives for supply to be responsive to demand over the shortest timeframe practicable, will drive more efficient wholesale market outcomes. What is practicable will depend on such things as constraints on information technology (IT), data processing, metering and the physical ability of energy producing and consuming assets to respond. A more efficiently functioning wholesale market will in turn provides the benefits of lower supply costs and lower retail prices for consumers.

The reasons for adopting the different periods of five minutes for dispatch and 30 minutes for settlement at the inception of the NEM were limitations in metering and data processing in the 1990s. Aligning dispatch and settlement intervals at five minutes means that financial incentives for participants are matched to the physical operation of the market. The benefit of five minute settlement over the existing five minute dispatch and 30 minute settlement is that it provides an improved price signal for the efficient use of and investment in generation and demand-side technologies. In particular, it signals the physical value of when a demand or supply response is needed by the power system, and rewards more accurately those who can deliver that response.

The 30 minute settlement regime results in an incentive to respond to expected 30 minute prices, rather than the five minute price at any point in time. This dampens the incentive for investments in the most flexible technologies. It can also lead to bidding behaviour and operational decisions that result in responses occurring up to 25 minutes after they are needed by the power system. This could increase the cost of supplying electricity in the short and long term. There is some evidence of this occurring in the market today.

Five minute settlement provides an improved price signal that would be technology neutral. It would promote productive, allocative and dynamically efficient outcomes by encouraging efficient operation in generation, use of energy services, and innovation and investment in an appropriate amount of flexible generation and demand response technologies. The result would be a more efficient mix of generation assets and demand response technologies over time leading to lower supply costs. This will benefit consumers as reduced wholesale electricity costs flow through to retail prices.

Five minute settlement is particularly important in the context of the current changes in generation technology and the evolving NEM. By improving the price signal for when a physical response is required in the power system, it signals when investments in flexible technologies are needed. This is likely to become even more important over time, as flexible technologies will be required to support the increasing penetration of

intermittent generation so that consumers can realise the benefits of enhanced reliability and system security.

Costs of five minute settlement

The 30 minute settlement arrangements have been in place for nearly two decades. All existing IT systems, metering infrastructure, and financial contracts have tended to be designed with reference to 30 minute settlement.

Therefore, despite the in-principle benefits identified with five minute settlement, the Commission is mindful that any change will disrupt existing processes and involve non-trivial costs. The overall market outcomes of five minute settlement would also depend on the classes of market participants it applied to. A change to five minute settlement would create one-off metering and IT system upgrade costs, and would also likely disrupt contracting arrangements.

The potential contract market disruption from a move to five minute settlement is of particular concern to the Commission. The contract market plays a crucial role in that it reduces price uncertainty for generators, retailers, major industry and consumers of electricity. It allows generators to manage risk, secure finance and provides signals for on-going investment in generation capacity. For retailers, it provides for security of supply to deliver price stability for consumers, and allows them to secure financing for their own operations. Given the importance of liquidity in the contract market, it is vital that disruption to this market is minimised.

Of primary concern is that a move to five minute settlement would potentially result in an initial reduction in the supply of cap contracts, a risk management product that retailers and large energy users use as protection against high spot prices. Under 30 minute settlement, gas peaking generators can offer and physically defend these caps. With five minute settlement, there is uncertainty as to whether these generators will be able to defend and offer the same volume of these contracts. Based on independent advice, it is estimated a move to five minute settlement could decrease the supply of caps by 23 per cent, corresponding to a reduction of 625 MW in the volume of cap contracts that would otherwise have been traded.

A substantial, immediate reduction in the supply of cap contacts is likely to increase wholesale prices and damage retail competition. A reduction in caps would increase barriers to entry for retailers, create incentives for market participants to manage risk via vertical integration or horizontal integration, and increase retail market concentration. This will result in higher prices for consumers. The Commission notes that the economics of new types of fast response and flexible technologies is constantly improving. However, they do not yet supply electricity on a significant scale and it is unclear whether they would replace the existing supply of caps that gas peaking generators currently sell.

Implementation

To be satisfied that the proposed adoption of five minute settlement is in the long term interests of consumers, the expected benefits from the improved price signal must be greater than the expected costs. If five minute settlement is to be implemented, the Commission's view is that the benefits would be maximised by:

- having mandatory five minute settlement for all wholesale market participants, rather than optional demand-side participation in five minute settlement on a permanent basis

- using revenue metering data, rather than supervisory control and data acquisition (SCADA) data, which while involving lower implementation costs, are less accurate and not widely available for all market participants.

Further, it has been identified that the costs and practical challenges of implementing five minute settlement - relating to contract market disruption, metering changes, and changes to IT systems - can potentially be mitigated and managed through the use of a transition period. The optimal transition period will allow for:

- existing and new generators to address any initial shortage of cap contracts from the introduction of five minute settlement

- the expiry of existing contracts and the negotiation of new contracts that account for the future implementation of five minute settlement

- upgrades five minute metering to coincide with routine scheduled maintenance or replacement

- a staged implementation of IT system upgrades to enable five minute settlement compatible systems.

Based on information relating to existing contracts and metering, the Commission considers that if five minute settlement was implemented, a staged transition period is appropriate.

Commission’s initial position

Given the change occurring in the NEM, the Commission's initial position is that:

- The adoption of five minute settlement would have a material benefit that is likely to outweigh the cost.

- Optional demand-side participation in five minute settlement would lead to relatively less efficient outcomes if it were allowed on a permanent basis, but it may be acceptable as a transition measure.

- The use of revenue metering is the preferred option for five minute settlement data collection rather than a profiling approach using SCADA systems. Interval meters would require reconfiguration or replacement to be capable of handling

five minute resolution data. There would be no changes required for accumulation meters used in residential and small business applications.

- There are costs and risks associated with any move to five minute settlement that arise from the disruption to the contracts market, accessing five minute data through existing meters, and the required replacement or upgrade of IT systems.
- To introduce five minute settlement it would be necessary to have a transition period to manage and mitigate the risks and costs identified with implementation.

The Commission's initial position is that if the rule change were made, an appropriate transition period for the implementation would be in the order of three years.

The Commission's initial position is subject to stakeholder feedback on detailed immediate and future costs and benefits of five minute settlement. Stakeholder feedback on the initial position will inform the Commission's draft decision on the rule change.

Contents

1 Introduction and background 1

1.1 Purpose of the directions paper 1

1.2 Sun Metals' rule change request 2

1.3 Context 4

1.4 Consultation on directions paper 5

1.5 Structure of this paper 6

2 Assessment framework 7

2.1 The role of wholesale electricity prices 8

2.2 Proposed assessment framework 9

3 Materiality of the problem 13

3.1 Sun Metals' view 13

3.2 Stakeholder views 13

3.3 Analysis 15

3.4 Commission's initial position 36

4 Impact on operation and investment 38

4.1 Sun Metals' view 38

4.2 Stakeholder views 38

4.3 Analysis: Responsiveness of generation and load 42

4.4 Analysis: Impact on hedging and risk management 56

4.5 Analysis: Incentives to invest in flexible technologies 67

4.6 Commission's initial position 71

5 Design issue: Optionality 73

5.1 Sun Metals' view 73

5.2 Stakeholder views 74

5.3 Analysis 77

5.4 Commission's initial position 82

6 Design issue: Metering 84

6.1 Sun Metals' view 84
6.2 Stakeholder views 84
6.3 Analysis 86
6.4 Commission's initial position 95
6.5 Potential changes to NER 96
7 Costs and transition 98
7.1 Sun Metals' view 98
7.2 Stakeholder views 98
7.3 Analysis 101
7.4 Commission's initial position 112
A Questions for stakeholders 115
Abbreviations 118

1 Introduction and background

In December 2015, Sun Metals Corporation Pty Ltd (Sun Metals) submitted a rule change request to the Australian Energy Market Commission (the AEMC or Commission). Sun Metals proposed that the time interval for financial settlement in the wholesale electricity market be reduced from 30 minutes to five minutes. The proposal involves:

- compulsory five minute settlement for generators, scheduled loads and market interconnectors
- a choice of either a five or 30 minute settlement interval for demand side participants, including retailers and large consumers.

The rule change process has so far featured:

- a consultation paper[1]
- two meetings of a diverse stakeholder working group, which the Commission convened to assist in its assessment of this rule change request. the group comprised of generators, gentailers, second tier retailers, new technology providers, representatives of small and large consumer groups, financial institutions, large load users and market institutions [2]

The two working group papers can be found on the Commission's website.[3]

At the second meeting of the working group in December 2016, stakeholders unanimously requested that the Commission undertake an additional round of consultation before making a draft decision. They identified this was a significant proposed rule change for the sector and understanding the Commission's initial implementation preferences was crucial, as it could materially affect the realised costs and benefits. The directions paper has been prepared in response to this feedback.

1.1 Purpose of the directions paper

This directions paper sets out the Commission's initial views on key issues arising from Sun Metals' rule change request. It provides details of how five minute settlement could be implemented. Stakeholders have indicated that this level of detail is required to understand the likely costs and benefits of the proposed rule change as the implementation will materially affect the realisation of any costs or benefits. The paper

1 AEMC, *Consultation Paper, National Electricity Amendment (Five Minute Settlement) Rule 2016*, 19 May 2016.

2 The working group consisted of representatives from AEMO, AER, AGL, Clean Energy Council, Energy Consumers Australia, EnerNOC, ERM Power, Energy Users Association of Australia, Infigen, Intergen, Macquarie Bank, Major Energy Users, Mojo Power, Origin Energy, Reposit, Stanwell, Sun Metals and Uniting Communities.

3 AEMC, http://www.aemc.gov.au/Rule-Changes/Five-Minute-Settlement#

will also explore the linkages between this rule change proposal and other current AEMC rule changes and reviews.[4] The Commission will use the comments received in response to the directions paper to inform its draft decision on the rule change.

1.2 Sun Metals' rule change request

The rule change request relates to the mismatch between dispatch and settlement intervals in the national electricity market (NEM). More detail can be found in the rule change request itself and the consultation paper.[5]

1.2.1 Issues raised by Sun Metals

Sun Metals submits that the mismatch between the current dispatch and financial settlement intervals leads to inefficiencies in the operation and generation mix of the market. Specifically, this aspect of the market design:

- accentuates strategic late rebidding, where generators have been observed to withdraw generation capacity in order to influence price outcomes
- impedes market entry for fast response generation and demand side response.

Further details of the current market arrangements are set out in the consultation paper.[6]

Sun Metals notes that batteries, some loads and some transmission systems are capable of responding in a single five minute dispatch interval. It submits that the capability of these technologies is not appropriately recompensed under the current arrangements and will therefore not be properly utilised.

Sun Metals provides two examples in support of its view that there is little incentive for fast response technologies to enter the market. These are summarised as follows:

1. A fast start generator being dispatched for one dispatch interval in response to a high five minute price. Through averaging, the 30 minute average price received by the generator would be less than the five minute price at the time that the generator was producing.
2. Loads, such as Sun Metals, having to restrict consumption over the whole 30 minute trading interval, to avoid high price events that may only last for a single five minute dispatch interval. This may be more disruptive for a load than a five minute response.

4 For example, the non-scheduled generation and load in central dispatch rule change, the system security market frameworks review and the distribution market model review.

5 AEMC, http://www.aemc.gov.au/Rule-Changes/Five-Minute-Settlement#

6 AEMC, *Consultation Paper, National Electricity Amendment (Five Minute Settlement) Rule 2016*, 19 May 2016 pp. 2-3.

Sun Metals submits that the average price may not be sufficient for investment in fast start generation, or for the operation of existing generation capacity. It also considers that the requirement for it to reduce consumption for a full half hour is disproportionately disruptive to the production of zinc and its associated economic benefit.

1.2.2 Sun Metals' proposed solution

To address the issues identified, Sun Metals proposes a five minute settlement regime that is:

- compulsory for generators,[7] scheduled loads and market network service providers (MNSPs)
- optional for other wholesale market participants.

Generators, scheduled loads and MNSPs would be settled on a five minute basis using:

- existing five minute prices calculated by the Australian Energy Market Operator (AEMO)
- energy from existing revenue meters, allocated to the five minute periods within a half hour using operational data from supervisory control and data acquisition (SCADA) systems.

SCADA systems are used to monitor and control industrial process, such as power station generating units.[8]

Sun Metals proposes that other wholesale market participants, including retailers and large consumers, could choose to be settled on either a five or 30 minute basis. All participants may choose, at their own cost, to install metering equipment capable of accurately measuring energy on a five minute basis.

Under Sun Metals' proposal, five minute settlement would be optional for non-scheduled loads. Therefore AEMO would need to operate concurrent five and 30 minute settlement for different participants. This arrangement would create an imbalance between the money earned by supply side participants settled on a five minute basis and the money paid by demand side participants, who could be settled on either a five or 30 minute basis.

Sun Metals proposes a new mechanism to correct the imbalance. The imbalance amount, which could be positive or negative, would be recovered entirely from those demand side participants who continue to be settled on a 30 minute basis.

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7 The five minute settlement regime would be compulsory for scheduled, semi-scheduled and non-scheduled market generators that sell electricity into the spot market at the spot price.

8 The proposed use of SCADA data and the differences between SCADA and existing metering for revenue purposes are discussed in section 5.2.1 of the consultation paper and section 2.2 of the December 2016 working group paper.

The rule change request does not include a proposed rule, but notes that changes to Chapter 3 of the National Electricity Rules (NER) would be necessary to implement the proposed solution.

1.3 Context

The Commission's assessment of this rule change request is being undertaken in the context of a series of structural changes in Australia's energy markets. One area of change is in the electricity generation sector, where low-emissions intermittent technologies are becoming increasingly prevalent. The adoption of more intermittent wind and solar generation, combined with the end-of-life retirement of existing large-scale synchronous generation, means that there is an increasingly important role for flexible generation to support the inherently variable output of wind and solar generation. Currently supply-side flexibility in the NEM is largely provided by hydro, gas peaking and diesel fuel generators.

The generation mix will change further as technology advancements improve the economics of faster and more flexible demand and supply solutions in the future. Given the change underway, it is increasingly important that the NEM market design provides the right price signals, as this will affect the incentives for the efficient use of generation assets, the efficient consumption of electricity, and efficient investment in generation and demand-side technologies. It is in this context that the Commission is considering which market design will provide the best outcomes for customers, while affording generators the opportunity to earn sufficient revenue from providing energy and ancillary services that maintain the security of the power system.

The reasons for adopting the different periods of five minutes for dispatch and 30 minutes for settlement at the inception of the NEM were limitations in metering and data processing at that time. Aligning dispatch and settlement intervals at five minutes means that financial incentives for participants are matched to the physical operation of the market. The benefit of five minute settlement over the existing five minute dispatch and 30 minute settlement is that it provides an improved price signal for the efficient use of and investment in generation and demand-side technologies. In particular, it signals the physical value of when a demand or supply response is needed by the power system, and rewards those who can deliver that response.

The 30 minute settlement regime results in an incentive to respond to expected 30 minute prices, rather than the five minute price at any point in time. This dampens the incentive for investments in the most flexible technologies. It can also lead to bidding behaviour and operational decisions that result in a generation or load response that occurs up to 25 minutes after it is needed by the power system. This could increase the cost of supplying electricity in the short and long term. There is some evidence of this occurring in the market today.

Five minute settlement provides an improved price signal that would be technology neutral. It would promote productive, allocative and dynamically efficient outcomes by encouraging efficient operation in generation, use of energy services, and innovation and investment in an appropriate amount of flexible generation and

demand response technologies. The result is a more efficient mix of generation assets and demand response technologies over time, lower supply costs, and benefits to consumers through lower retail prices.

The 30 minute settlement arrangements have been in place for nearly two decades. All existing IT systems, metering infrastructure, and financial contracts have tended to be designed with reference to 30 minute settlement. Therefore, despite the in-principle benefits identified with five minute settlement, the Commission is mindful that any change will disrupt existing processes and involve non-trivial costs.

The potential contract market disruption from a move to five minute settlement is of particular concern to the Commission. The contract market plays a crucial role in that it reduces price uncertainty for generators, retailers, major industry, and consumers of electricity. Of major concern is that a move to five minute settlement would potentially result in an initial reduction in the supply of cap contracts, a risk management product primarily offered by gas peaking generators that retailers and large energy users use as protection against high spot prices. With five minute settlement, there is uncertainty as to whether these generators will be able to defend and offer the same volume of these contracts. The Commission notes that the economics of new types of fast response and flexible technologies is constantly improving. However, they do not yet supply electricity on a significant scale and it is unclear whether they would replace the existing supply of cap contracts that gas peaking generators currently sell.

This paper explores whether the enduring benefit of five minute settlement outweighs the implementation costs and risks, and considers whether those costs and risks could be mitigated through an appropriate transition period.

As discussed above, the paper sets out the Commission's preliminary reasoning and views on these issues. It seeks feedback from stakeholders on the immediate and future costs and benefits of five minute settlement to inform the Commission's draft decision on the rule change.

1.4 Consultation on directions paper

Stakeholders are encouraged to provide feedback throughout this process. Feedback can include complementary or competing analysis that can contribute to the Commission's deliberations.

The Commission invites submissions on this directions paper by no later than 18 May 2017.

Submissions should quote project number “ERC0201” and may be lodged online at www.aemc.gov.au or by mail to:

Australian Energy Market Commission

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SYDNEY SOUTH NSW 1235

1.5 Structure of this paper

The remainder of this paper is structured as follows:

- Chapter 2 sets out the proposed framework for assessing the rule change proposal.
- Chapter 3 considers the materiality of the problem.
- Chapter 4 presents analysis on the effect of five minute settlement on operation and investment.
- Chapter 5 discusses the merits of demand side participants being able to opt into five minute settlement.
- Chapter 6 analyses metering requirements under a five minute settlement scenario.
- Chapter 7 considers whether an appropriate transition period could mitigate the costs and risks of introducing five minute settlement.

2 Assessment framework

This chapter sets out the requirements under the National Electricity Law (NEL) that the AEMC must satisfy in considering the rule change request, and provides detail of the proposed approach for assessing the rule change request. Stakeholder feedback on this proposed assessment framework is welcomed.

The NEL confers on the Commission the ability to take one of three potential actions in response to receiving a valid rule change request.[9] It can make the proposed rule if it is satisfied that the rule is likely to contribute to the achievement of the national electricity objective (NEO). Alternatively, it can make a more preferable rule which is different to the proposed rule if it is satisfied that, having regard to the issues raised by the rule change request, the more preferable rule is likely to better contribute to the achievement of the NEO than the proposed rule. The third option is for the Commission to not make a rule.

Accordingly, the Commission's assessment of this rule change request will consider whether the proposed rule promotes the NEO, which is:

"to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:

> "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:
>
> (a) price, quality, safety, reliability and security of supply of electricity; and
>
> (b) the reliability, safety and security of the national electricity system.[10]"

The objective captures the three dimensions of efficiency: productive (efficient operation), allocative (efficient use of) and dynamic efficiency (efficient investment).[11]

As noted above, the Commission may only make the proposed rule and change the National Electricity Rules (NER) if satisfied that the change will, or is likely to, contribute to the achievement of the NEO. As such, the Commission must consider whether changing the NEM settlement arrangements would be in the long term interests of electricity consumers.

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9 A valid rule change request is a request that the AEMC will act on under Division 3 of the NEL, having had regard to the matters set out in s. 94(1) of the NEL.

10 NEL, s. 7.

11 Productive efficiency means goods and services should be provided at lowest possible cost to consumers; allocative efficiency means that the price of goods and services should reflect the cost of providing them, and that only those products and services that consumers desire should be provided; dynamic efficiency means arrangements should promote investment and innovation in the production of goods and services so that allocative and productive efficiency can be sustained over time, taking into account changes in technologies and the needs and preferences of consumers.

Based on a preliminary assessment of this rule change request, the Commission considers that the relevant aspects of the NEO are the efficient investment in, and operation and use of electricity services with respect to the price of electricity.

2.1 The role of wholesale electricity prices

The rationale for the proposal is to increase the efficiency of spot market prices. The spot market price signals the value of generating and consuming electricity at different points in time and the physical value of when a demand or supply response is needed by the power system.

All generation is required to be settled through the wholesale market at the spot price and in the short term it signals to:

- generators to increase or decrease supply, thereby promoting efficient outcomes
- consumers who have the ability and are directly or indirectly exposed to wholesale market prices, to similarly efficiently respond by increasing or decreasing their consumption based on price.[12]

The spot price also provides the signal and incentive for parties to negotiate and enter into contracts. The related contract market facilitates the efficient investment in generation capacity or demand-side technologies.

The contract market plays a crucial role as it provides a mechanism to manage parties exposure to price volatility and uncertainty associated with the wholesale spot market outcomes. By promoting greater certainty for generators, retailers, major industry, and consumers of electricity, it provides a market-based mechanism to support efficient investment over time in generation capacity. Generators, through financial market contracts, can obtain a degree of revenue certainty and secure project finance while retailers are able to deliver price stability for consumers, and secure financing for their own operations.

The presence of retailers in the energy market means that most consumers do not need to have direct wholesale market exposure.[13] Retailers act as an intermediary between end users and the wholesale energy market. In this role retailers manage the risk of matching variable demand over time with energy sourced from the NEM, where prices can vary by trading interval from the market price cap (currently $14,000/MWh) to the

12 This can be done either by becoming a wholesale market customer or through contractual agreements with retailers. Consumers may then undertake measures to manage their electricity use and limit this exposure, for example, they may engage with energy management experts.

13 Retailers can, and do, develop service offerings to attract customers that incorporate a range of pricing strategies from offering a fixed price service to offering some form of exposure to price volatility on the basis that the customer may want to, and can manage that exposure and can potentially end up with a lower cost service than would be offered under a fixed price service offering.

market price floor (currently -$1000/MWh).[14] This is done by entering into contractual arrangements via either over-the-counter or exchange-traded wholesale electricity contract products. The varying types of hedge contracts that exist fix participants exposure to the price of electricity, or provide greater price certainty.

For the spot and contracts market to work effectively and deliver long term benefits to consumers, the NEM price settling process should be sufficiently transparent and robust. This provides market participants the confidence that these signals are generally reflective of underlying supply and demand conditions. Further, prices should be sufficiently granular so as to accurately reflect the value of electricity at different locations and different points in time. This rule change concerns the temporal granularity of the market price signal.

2.2 Proposed assessment framework

The Commission uses an assessment framework to evaluate whether the proposed rule, if made, is likely to promote the NEO. As noted above, the key areas of the NEO that will likely be considered are the efficient investment in, and operation and use of electricity services with respect to the price of electricity. The three dimensions of efficiency are integral to the design of the assessment framework.

With respect to whether changing the NEM settlement arrangements would be in the long term interests of electricity consumers, market efficiency is comprised of:

- Productive efficiency – does the rule change create better incentives for more efficient operation of the market and therefore minimise the costs of supply?
- Allocative efficiency – does the rule change encourage resources to be used or consumed by consumers of electricity that most value the service?
- Dynamic efficiency – does the rule change improve incentives for investment and innovation and promote allocative and productive efficiency over time?

Allowing for these aspects of efficiency, the Commission proposes an assessment framework that includes the following factors:

- **Prices that reflect the marginal cost of supply and value of its use.** To promote efficient outcomes in the electricity market, spot prices should generally reflect the marginal cost of supply and value of consuming electricity. A shorter settlement interval would lead to prices that more accurately reflect the value of supplying or consuming electricity at different times. The Commission will consider the extent to which the proposed changes would improve price signals in the NEM, and whether this would lead to more efficient dispatch outcomes and investment decisions.

14 For the market price cap value see AEMC, http://www.aemc.gov.au/Australias-Energy-Market/Market-Legislation/Electricity-Guidelines-and-Standards/Schedule-of-Reliability-Settings-(MPC-and-CPT-(5), 10 April 2017. For market floor price see NER clause 3.9.6.

- **Valuing generation and demand response flexibility.** Price signals also signal the physical value of when a demand or supply response is needed by the power system. The Commission will consider whether the proposed changes would enable the market to deliver enough generating plant or demand response to meet the demand and supply balance at the time when it is physically needed by the power system.

- **Technology neutrality.** The Commission will examine the extent to which the proposed changes would be technology neutral. Technology neutrality is important in that it enables an efficient mix of generation and consumption market responses in the short-term and an optimum mix of supply-side and demand-side investment in the longer term. This minimises the costs of supply over time.

- **Price risk exposure.** All electricity generated and consumed in the NEM is transacted at the spot price. Generators can physically manage their exposure through bidding at or above the cost of supply, so as to avoid being dispatched if losses would be incurred. The mismatch between dispatch and settlement may create undue risks for participants, as the ability of participants to respond to changes in the market (via the dispatch process) is not well aligned with financial outcomes (settlement). The Commission will consider the impact of aligning dispatch and settlement on the ability of market participants to manage their price risk exposure.

- **Efficient risk allocation via contracting.** Participants can financially manage their exposure to spot prices by entering into contractual agreements that provide greater price certainty. These arrangements can involve the buyer of a contract paying the seller to take on some or all of the price risk to which the buyer is exposed. While these arrangements occur outside of the NEM, the Commission acknowledges that changes to the NEM market design would impact on the incentives for participants to buy and sell hedging contracts. The Commission will consider the potential impact of the proposed changes on the ability of market participants to efficiently allocate risk through contracting arrangements.

- **Supply and demand-side competition.** A more accurate NEM spot price may provide better incentives for demand-side participation, such as consumers deciding to curtail consumption, delay consumption, or install their own generation capacity. These responses have the potential to reduce price spikes and average prices. More accurate spot prices may also encourage greater supply side competition with generators entering the market that are able to take advantage of spot price variability or existing participants investing in additional flexibility. The Commission will consider the extent to which this may occur if five minute settlement is implemented.

- **Regulatory and administrative burden.** The Commission will consider the potential regulatory and administrative burden on market participants that may arise if the proposed rule were to be implemented. Through this rule change

process, the Commission seeks to understand the magnitude and distribution of the costs so that they can be compared against the likely benefits of making the change. The costs associated with the proposed changes would involve once-off costs associated with the transition and potential on-going costs associated with the new regime.

The Commission acknowledges that the assessment of the likely costs and benefits of the proposed changes will be an important component of the Commission's assessment of the rule change request. The proposed changes would likely result in costs and/or benefits accruing to most market participants, which would ultimately impact on the cost of electricity for end users. This paper sets out the Commission's initial views on design and implementation of a move to five minute settlement, addresses the assessment factors listed above and seeks stakeholder feedback on detailed costs and benefits.

The table sets out the sections of the report which address each assessment factor.

Assessment factor	Main location/s of assessment factor analysis in this report
Prices that reflect the marginal cost of supply and value of its use	Chapter 3 – Materiality Chapter 4 – Operation and investment
Valuing generation and demand response flexibility.	Chapter 3 – Materiality Chapter 4 – Operation and investment
Technology neutrality	Chapter 3 –Materiality Chapter 4 – Operation and investment
Price risk exposure	Chapter 3 – Materiality Chapter 4 – Operation and investment
Price risk allocation	Chapter 3 – Materiality Chapter 4 – Operation and investment
Supply and demand side competition	Chapter 4 – Operation and investment
Regulatory and administrative burden	Chapter 5 – Optionality Chapter 6 – Metering Chapter 7 – Costs and transition

Question 1 Assessment framework

(a) How suitable is the proposed assessment framework for this rule change request?

(b) Are there any additional factors that should be considered in assessing this rule change request?

3 Materiality of the problem

The analysis in this chapter assesses the materiality of the problem associated with the existing five minute dispatch and 30 minute settlement framework, and therefore the benefit of moving to five minute settlement. It does this through comparing the existing regime with the proposal for five minute settlement. The chapter explores the issues arising from the current mismatch between dispatch and settlement and the benefits associated with aligning dispatch and settlement in the context of a NEM undergoing a significant transition. In particular, it assesses whether matching the financial incentives to the physical operation of the market improves price signals, and how it affects incentives for the efficient operation and use, and investment in the power system.

3.1 Sun Metals' view

Sun Metals was of the view that the current arrangements:

- accentuate strategic late rebidding, where generators have been observed to withdraw generation capacity in order to influence price outcomes
- impede market entry for fast response generation and demand side response.

In providing this view, Sun Metals did not undertake any analysis or quantification of the materiality of the problem associated with the existing 30 minute settlement framework.

3.2 Stakeholder views

The majority of submissions to the consultation paper broadly acknowledged that there was a theoretical problem with having a misalignment between the dispatch and settlement periods. However, stakeholders were divided as to the materiality of the problem, especially given the implementation issues involved. To gauge the materiality of the problem, the benefits from the move to five minute settlements need to be identified and assessed.

Several stakeholders identified the improvement to the price signals that arises from aligning dispatch and settlement.[15] The AER explained that this alignment would more accurately reflect participants' behaviours in their market revenues, which would value flexibility and responsiveness, encouraging new technologies and greater demand-side response.[16] Intelligent Energy Systems submitted that the current arrangements impose risks for participants that respond on the basis of one price, but

15 Consultation paper submissions: Australian Energy Storage Alliance, p. 4; The Australia Institute, p. 2; Clean Energy Council, p. 3; Ecoult, p. 4; Genex Power, p. 1; Melbourne Energy Institute, p. 8; Reposit Power, p. 1; UnitingCare Australia, p.10; Wärtsilä, p. 9; ZEN Energy, p. 2.

16 AER, submission to consultation paper, p. 1.

receive another, or who simply do not respond due to a confusing outcome.[17] Engie, ERM Power and Origin Energy noted that as dispatch and settlement timing becomes closer to being instantaneous, the market would be increasingly efficient, however the technical, physical and economic costs for achieving this outcome needed to be recognised.[18] Similarly, CS Energy recognised the theoretical value of this move towards more marginal decision making, suggesting that it should improve allocation of resources and "if done well, will satisfy the National Electricity Objective".[19] Energy Consumers Australia indicated that the increased wholesale market rigor and improvements in the efficiency of generator behaviour would be in the long term interests of consumers.[20]

Another perceived benefit raised by several stakeholders was the increase in value for flexible response, particularly with the increases in renewable energy capacity installed in the NEM.[21] Wärtsilä noted that despite higher accuracy forecasting tools and better scheduling, increased renewable energy increases the probability of a sudden change in generation, which adds to the volatility of the system. As a result, getting a price signal that values flexible response is becoming increasingly important.[22] AEMO provided a worked example illustrating the increase in profitability of flexible plant under five minute settlements.[23] The Clean Energy Council argued that the move to five minute settlements should be viewed purely on the benefits to energy and ancillary services and the lowering of barriers to entry for new technologies.[24]

Some stakeholders also raised concerns that strategic rebidding remained a problem in the market.[25]Reposit Power considered that the move to five minute settlements would reduce the opportunity for price manipulation, resulting in a more efficient price.[26] ZEN Energy submitted that the current market rules are flawed as they provide incentives for private firms to act in ways that destabilise the market.[27] The Australia Institute also considered that the move to five minute settlements would increase competition in the market with increased new technologies and demand-side participation, which would lead to lower wholesale prices.[28] The Australian Energy

17 Intelligent Energy Systems, submission to consultation paper, p. 2.

18 Consultation paper submissions: Engie, pp. 2-3; ERM Power, p. 4; Origin Energy, p. 1.

19 CS Energy, submission to consultation paper, p. 1.

20 Energy Consumers Australia, submission to consultation paper, p. 3.

21 Consultation paper submissions: AEMO, p. 2; Australian Energy Storage Alliance, p. 4; The Australia Institute, p. 2; Ecoult, p. 4; Energy Consumers Australia, p. 5; Wärtsilä, p. 4; ZEN Energy, p. 2.

22 Wärtsilä, submission to consultation paper, p. 5.

23 AEMO, submission to consultation paper, p. 5.

24 Clean Energy Council, submission to consultation paper, p. 2 .

25 Consultation paper submissions: Intelligent Energy Systems, p. 7; Liquid Capital Markets, p. 1; Melbourne Energy Institute, p. 5; Wärtsilä, p. 4.

26 Reposit Power, submission to consultation paper, p. 1.

27 ZEN Energy, submission to consultation paper, p. 2.

28 The Australia Institute, submission to consultation paper, p. 1.

Storage Alliance and Energy Consumers Australia both noted that advances in metering and data processing have made this rule change both feasible and timely.[29]

In contrast, other stakeholders have suggested that the problem is immaterial. Origin Energy, Stanwell and Hydro Tasmania noted that investments in fast start generation and demand response in the NEM are already occurring, which contradicts the assertion that the current arrangements impede market entry of fast start plant.[30] Origin Energy also suggested that the concerns around the materiality of strategic bidding, and misalignment are overstated.[31] Stanwell and Major Energy Users both suggested that the problem this rule change addresses is immaterial in light of other inefficiencies in the market.[32] Pacific Aluminium suggested that if there is confidence in pre-dispatch and the bidding process reflects supply and demand in the market, the material difference between five or 30 minute dispatch is less substantial.[33]

Stakeholders also raised concerns around the implementation of the rule change. These concerns are explored in detail in the following chapters, but at a high level they include concerns around five minute settlement being optional for demand-side participants, the proposed use of operational SCADA data for profiling 30 minute energy, and potential impacts on the liquidity of hedging contracts. There was a general view that cost of implementing the change will outweigh the potential benefits.[34]

3.3 Analysis

In the previous chapter, the Commission outlined the assessment framework that it will apply in considering this rule change. It noted the efficiencies considered are:

- Productive efficiency – does the rule change create better incentives for more efficient operation of the market and therefore minimise costs of supply?
- Allocative efficiency – does the rule change encourage resources to be used or consumed by consumers of electricity that most value the service?
- Dynamic efficiency – does the rule change improve incentives for investment and innovation and promote allocative and productive efficiency over time?

This implies the proposed rule change promotes the NEO, if it improves the efficient operation, use and investment in the electricity market over time, in such a way that promotes the long term interests of consumers. Chapter 2 highlighted the market

29 Consultation paper submissions: Australian Energy Storage Alliance, p. 4; Energy Consumers Australia, p. 5.

30 Consultation paper submissions: Hydro Tasmania, p. 1; Origin Energy, p. 2; Stanwell, p. 2.

31 Origin Energy, submission to consultation paper, p. 2.

32 Consultation paper submissions: Major Energy Users, pp. 8-9; Stanwell, p. 5.

33 Pacific Aluminium, submission to consultation paper, p. 1.

34 Consultation paper submissions: Australian Energy Council, p. 3; ERM Power, p. 1; Major Energy Users, p. 10; Snowy Hydro, p. 1.

related factors or conditions to make this assessment, which involves evaluating whether the proposed rule improves the alignment of price with cost, technology neutrality and the allocation of risk.

To determine the materiality of the problem with 30 minute settlement, and the potential benefits of adopting the proposed rule change, this section examines:

- the benefit of aligning dispatch and settlement, and having an improved signal for the physical value of when a demand or supply response is needed by the power system
- evidence of how the existing 30 minute settlement framework is affecting price signals in the NEM
- the NEM market design, the changing generation mix of the NEM and the need for future investment in generation in the NEM
- the incentive for late rebidding.

Each of these is discussed in further detail below.

3.3.1 Benefit of aligning dispatch and settlement at five minutes

A physical requirement of power systems is that demand and supply must be balanced in real-time. Ideally, given the dynamic nature of demand and supply, which vary continuously, the price signal would also vary in real-time. A market where the price provides signals and incentives for supply to be responsive to demand over the shortest timeframe practicable, will ensure a physical response of demand or supply at a time that it is required by the power system. What is practicable will in part depend on constraints on information technology (IT), data processing, metering, and the physical ability of current and emerging generation technologies to respond. Having such a price signal will drive more efficient wholesale market outcomes, which in turn provides the benefits of lower supply costs and lower prices for retail consumers.

The current arrangements for dispatch and settlement have been in place since the start of the NEM in December 1998.[35] There were pragmatic reasons for adopting different periods for dispatch and settlement at the NEM's inception. The choice of a 30 minute settlement period, rather than five minute settlement, reflected the limitations of IT technology and metering in the late 1990s to deal with such large amounts of data.[36] There was broad support in submissions for the view that if the NEM was being designed today, given the improvements in computer process power and data handling capability, dispatch and settlement periods would be aligned.

Aligning dispatch and settlement intervals at five minutes means that financial incentives for participants are matched to the physical operation of the market, over

35 NECA, *National Electricity Code*, version 1, 19 November 1998.

36 ACCC, *Applications for authorization – National Electricity Code*, 10 December 1997, p. 60.

the shortest practicable timeframe. This provides for an improved price signal for the efficient, operation, use of and investment in generation and demand-side technologies. Importantly, by rewarding those that can deliver a response within the dispatch period, it also signals the physical value of when a demand or supply response is needed by the power system. This enables the market to deliver enough generating plant or demand response to meet the demand and supply balance.

The mismatch or misalignment of dispatch and settlement that currently exists means that rather than supplying electricity on the basis of five minute prices, generators have an incentive to supply electricity and respond on the basis of the expected 30 minute prices. Similarly, load considers the appropriate response based on the expected 30 minute settlement outcome rather than the marginal dispatch interval price. Responding to expected 30 minute prices mutes the five minute pricing signal. In a practical sense, 30 minute settlement creates the risk that generation and load may be responding to a price signal up to 25 minutes after the dispatch interval where a high price signalled it was needed by the power system. By distorting bidding behaviour and operational decisions, it decreases efficiency in the wholesale market and increases the cost of supplying and using electricity over the short and long term.

Improving price signals is critical in the NEM, as prices should incentivise:

- the ongoing efficient operation and use of plant (productive efficiency)
- efficient use or consumption of electricity (allocative efficiency)
- efficient investment and innovation in generation and demand-side technologies over time (dynamic efficiency).

How the efficiency outcomes are promoted under five minute settlement compared with 30 minute settlement, are discussed in greater detail below. The analysis separates the static productive and allocative efficiencies of efficient operation and use, from the dynamic efficiency associated with investment and innovation.

Efficient operation and use

The incentives for efficient operation and use under 30 minute versus five minute settlement are particularly evident in the event of price spikes. The Commission assesses two types of price spikes and contrasts the outcomes for those technologies that can and cannot respond to the higher price within the five minute dispatch interval.

Late price spike

The mismatch or misalignment of dispatch and settlement means that generators are compensated on the basis of the simple average of the six five minute dispatch intervals in each 30 trading period. This has in the past resulted in an incentive for late rebidding behaviour involving a withdrawal of capacity and an increase in price in the

last five minute interval.[37] By doing this generators are able to earn a higher price over the 30 minute interval.

Such behaviour creates artificial risk, as price spikes are unrelated to any underlying uncertainty and increases costs in the wholesale market. This affects those loads that are spot exposed. While they still may be able to react to the higher spot price in the last five minute interval, under 30 minute settlement they still face the effect of that higher price in the previous dispatch intervals of the settlement period. Any large increase in price in the final interval will also increase the retail prices faced by consumers, effecting their efficient consumption decisions. Finally, flexible generation technologies able to respond to the higher price will not get the full reward for this capability. It may mean they choose not to operate even though the price is signalling that it would be physically valued by the power system.

Under five minute settlement the incentive to create conditions to increase price in the last period is removed. That said, the Bidding in Good Faith rule change introduced in 1 July 2016, was designed to curb this incentive to create late spikes through rebidding behaviour.[38]Initial analysis suggests that since the rule change was made, this behaviour has declined. The issue of strategic bidding is described further in section 3.3.4.

Early price spike – non-five minute responsive generation

If a price spike occurs in the first dispatch interval, under the 30 minute settlement any generation that occurs in the trading interval containing that dispatch interval will share the benefit of the price spike. This provides an incentive for those generators that cannot respond to the price spike in the initial dispatch periods, but can respond within the 30 minute period, to ramp up and generate. This leads to the "piling in" phenomenon where large levels of generation are offered at a reduced price at a time when it is not necessarily valued by the power system or market. In fact, the generation can be occurring up to 25 minutes after it is required by the power system. Further, to maximise their share of the initial spike, they are likely to bid prices well below the short run marginal cost of generation to ensure being dispatched.

The result of piling in can be a large price change within the 30 minute period. Trading intervals can include both very high prices and potentially negative prices (see for example Figure 3.4). The existing framework is therefore incentivising behaviour that may be creating a degree of artificial volatility in the market. This volatility is not a function of the underlying uncertainty, market risk or system need. It is driven by the price bidding behaviour of participants. To the extent that there is an increase in risk, this would also increase the cost of supply and retail prices for consumers.

However, a key argument made in support of the existing framework is the role that averaging dispatch interval prices over a 30 minute trading interval has on risk

37 AEMC, *Bidding in Good Faith*, final determination, 10 December 2015.

38 AEMC, *Five Minute Settlement Working Group, Working Paper No. 1*, 12 October 2016, Figure 7, p. 18 and Figure 9, p. 20.

management. In particular, it is argued it allows existing gas peaking generators who cannot currently respond within the five minute timeframe, to provide cap contracts to the market. The important role of caps and the potential issues the introduction of five minute settlement creates are discussed further in section 4.4.

Early price spike – five minute responsive generation (or load)

Generation that can respond in a short timeframe under 30 minute settlement, faces the risk that the final settlement price may well be less than the minimum price a participant had indicated they were willing to accept. This creates revenue uncertainty. A possible way to manage this risk is for rapid response and short duration generators, including batteries, hydro and diesel generators, to bid prices above the short-run marginal cost of generation. The magnitude of any price uplift by such participants in response to such uncertainty would need to be sufficient so that the participant's expected return from the end of trading interval 30 minute settlement price was at least equal to the short run marginal cost of being dispatched. A similar issue arises for flexible load.

The current 30 minute settlement framework effectively makes operating flexible rapid response technologies for generation in the NEM more financially risky. By not providing appropriate rewards for more flexible technologies that can respond to the price spike, there is the potential for such resources to choose not to participate in the market at a time when a response is physically valued by the power system to balance supply and demand. Over any 30 minute trading interval this risks creating productive inefficiency through a sub-optimal and higher cost supply mix. Further, and similarly, there will be allocative inefficiency, to the extent there is a sub-optimal level of consumption or demand response over the 30 minute settlement period.

Early price spike – stylised example

The stylised numerical example in Table 3.1 highlights the incentives that exist under the current framework. It assumes that:

- a rapid response generator, such as a battery, bids capacity at a marginal cost of $600/MWh and can respond within a five minute dispatch interval
- a fast response generator, such as a gas peaking plant, bids capacity at a marginal cost of $300/MWh, but can only respond fast enough to participate in dispatch intervals three to six.

Table 3.1 Stylised example – impact of 30 minute settlement

Period	Price ($/MWh)
DI1	600
DI2	600
DI3	300
DI4	300
DI5	300
DI6	300
Settlement	400

In the example, the effective price due to the 30 minute settlement period is $400/MWh. For the different generators bidding their respective short run marginal cost will result in:

- the rapid response generator receiving a trading interval price that is one third less than the generators minimum bid price of $600/MWh
- the fast response generator who participated in dispatch intervals 3 to 6 receiving a trading interval price one third higher than this minimum bid price of $300/MWh.

All other things being equal, in order to recover the short run marginal cost over the 30 minute settlement period:

- the rapid response generator would need to bid $1200/MWh in dispatch intervals 1 and 2, which is 100 per cent higher than its marginal cost[39]
- the fast response generator could place a minimum bid of $150/MWh in dispatch intervals 3 to to 6, which is 50 per cent lower than its marginal cost.

The results contrast to the outcome that would arise under five minute settlement. In the above example, under five minute settlement the price at which a generator is dispatched would be equal to the actual settlement value they receive and they would receive no less than their bid price.

Early price spike – summary

The analysis highlights that with an early price spike under the existing 30 minute settlement regime, generation that cannot respond immediately, but can generate within the 30 minute period has an incentive to:

39 If rapid response generators have an expectation of other generators piling in with a resulting further negative impact on the settlement price, then their bids will need to be even higher.

- manage risk by bidding at a price that is below the cost of generation
- operate the plant in such a way that they dispatch at a time when their generation is not physically valued by the power system
- behave in a way that creates artificial volatility, uncertainty and risk for wholesale market participants.

In contrast, for generation that can respond within the five minute dispatch interval to the early price spike, it:

- creates an incentive to manage risk of price uncertainty inherent in after-the-event 30 minute settlement, by bidding at a price that is above the marginal cost of generation
- potentially creates the incentive to avoid being dispatched, even though the dispatch price highlights that their generation is physically valued by the power system in that interval
- potentially creates risks for the ongoing operation and financial viability of flexible and fast response technologies.

Similar issues that arise in the operation of fast and flexible generation with 30 minute settlement, apply to the incentives to use fast and flexible load technologies.

The contrasting outcomes highlight that in principle, the existing misalignment between dispatch and settlement results in a distorted wholesale price signal. This creates incentives for inefficient asset operation by electricity generators, inefficient consumption of electricity services, and leads to higher costs of supply over a 30 minute period. This will be realised downstream by retail customers paying higher prices for electricity. The price signal is also not technology neutral, in that it supports the viability of existing incumbent generation at the expense of flexible fast response technologies that could better respond to the price spike. This is particularly important in considering how 30 minute settlement effects efficient innovation and investment over time.

Efficient investment over time

In a static world, where there is no change in underlying technology or demand and supply, investment in the broader energy supply sector will effectively only occur in response to the replacement of end-of-life plant. In this scenario, prices are not critical for signalling the need for new investment. They instead provide a signal for the efficient use of existing plant, ensuring the lowest marginal cost plant is optimally dispatched to satisfy current demand.

A static productive and allocative efficiency assessment, based on examining whether the lowest cost option is available for balancing supply and demand, does not highlight the full extent of the impact of the muted price signal. This is especially the case where technological change is occurring and where considerable future

investment is likely to be required in the next decade, such as is currently the case in the NEM (section 3.3.3 contains further discussion). An important consideration with the proposed rule change is the impact on dynamic efficiency, which is concerned with the optimal rate of innovation and investment to improve production processes over time, thereby reducing long-run costs.

Over the medium- to long-term, a price signal that is not technology neutral will deter efficient investment and innovation. The misalignment of dispatch and settlement creates the potential for investments in slower response technologies being favoured by investors over those with greater flexibility at the margin. This dynamic inefficiency from a distorted resource mix will have a more enduring effect, as downstream retail customers in the longer term will pay higher prices for electricity than they otherwise should over a sustained period of time.

Newer fast response technologies offer more flexible performance. Currently they have relatively high costs, although their economics is continually improving. A worst case scenario of the existing framework would be where the misalignment of dispatch and settlement creates incentives to invest in slower response technologies in future that are not only less valued by consumers in a particular five minute interval, but also involve a higher cost of supply. For example, this could arise due to the higher ancillary service requirements associated with operating the market with relatively inflexible plant.

Summary

Based on the assessment of incentives and the potential static and dynamic inefficiencies that arise under 30 minute settlement, there appears in principle to be a material problem with the current framework. This implies similarly that there are in principle material benefits associated with the proposed rule change.

To explore the issue of materiality further, the Commission in the following section examines whether there is evidence of the distorted behavioural incentives in the NEM outlined above.

3.3.2 The price signal from 30 minute settlement in the NEM

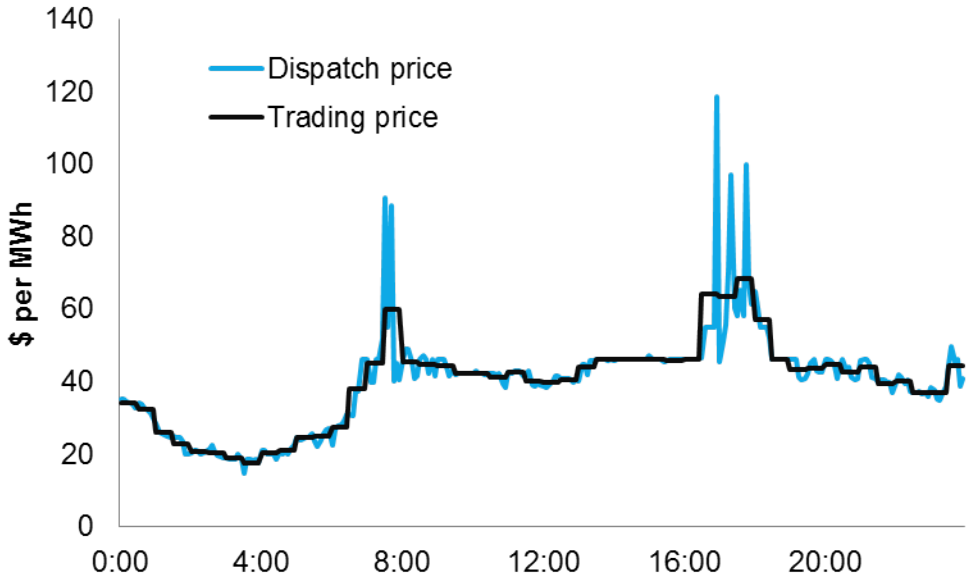
Working Group Paper 1 highlighted evidence of variation between the settlement price and the individual dispatch interval prices.[40]This is relevant to analyse the magnitude and frequency of the variation, as this variation indicates how effective the five minute price signal is, and whether there is a difference in incentives created by five minute and 30 minute prices. Evidence of higher and more frequent variation suggests the five minute price signal has a muted effect. It goes to supporting the materiality of the problem with 30 minute settlement, and the benefit of moving to five minute settlement.

40 AEMC, *Five Minute Settlement Working Group, Working paper No. 1*, 12 October 2016.

The analysis here focuses on the variation observed in the NEM between dispatch prices and the effective price over the 30 minute settlement period. As highlighted in the previous section price differences within the 30 minute intervals have the potential to influence the marginal generation and consumption decisions of market participants. To the extent they impact on expected total revenues for individual market participants, they may also have a significant impact on incentives for the efficient operation and use of generating plants, and incentives to invest in demand-side technologies. For example, a very fast response technology may ideally seek to only participate in a single dispatch interval. Yet under 30 minute settlement, they can only expect to receive the average trading interval price, rather than the actual five minute dispatch interval price.

Figure 3.1 highlights typical variation between five minute and 30 minute prices.[41] It sets out a comparison of dispatch prices and trading prices on 18 May 2015 in South Australia - an example of a day where the power system was operating under normal conditions, and where the difference between dispatch and trading prices can be observed. The key observation being the price smoothing effect of 30 minute settlement compared to five minute settlement. Many submissions have indicated that the volatility of five minute prices, and the price smoothing effect of 30 minute settlement is a desirable characteristic, as it reduces risk and facilitates the supply of cap contracts to the market by peaking generators such as open cycle gas turbines (OCGTs). The Commission notes though that it would be wrong to conclude from any historical analysis that the volatility associated with five minute dispatch prices, would continue in the presence of five minute settlement. With five minute settlement it would be expected that incentives would change, resulting in different bidding strategies and responses by generators.

Figure 3.1 Comparison of five minute and 30 minute prices (SA, 18 May 2015)



41 AEMC, *Five Minute Settlement Working Group, Working paper No. 1*, 12 October 2016, p. 9.

The magnitude of the variation in prices between five minute and 30 minute settlement across the NEM is highlighted in Figure 3.2, which also appeared in Working Group Paper 1.[42]

Figure 3.2 Average annual variation by region (2009 to 2016)

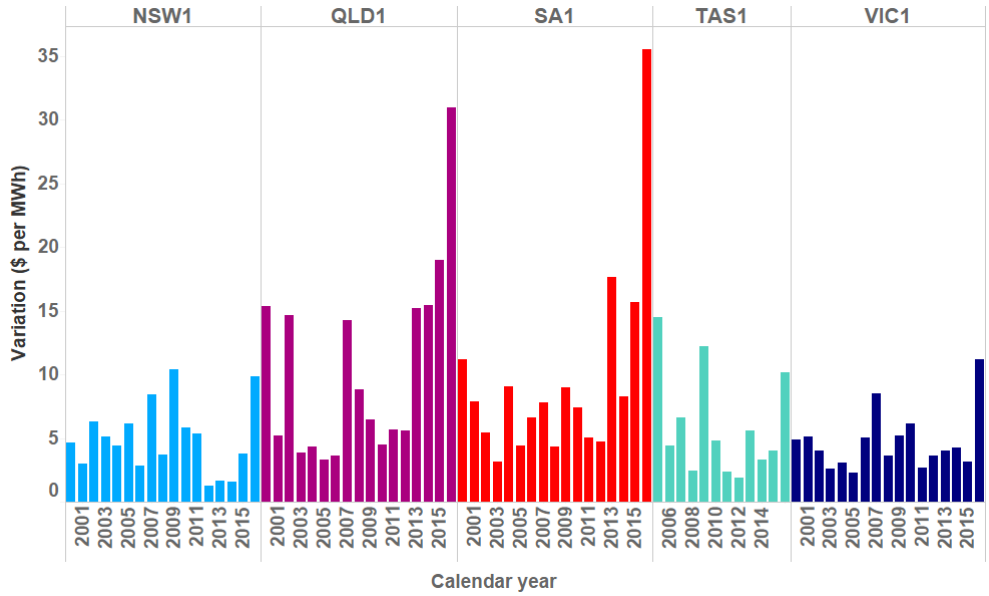


Figure 3.2 plots the annual average of absolute difference between the five minute dispatch prices and corresponding 30 minute settlement trading prices. This does not quantify inefficiency or benefits in absolute terms. Rather, the difference provides an indication of whether at any point in time the five minute dispatch price is a reasonable reflection of what participants will pay or are being paid. A smaller difference suggests that the 30 minute trading price is providing a good incentive for participants to respond to what is required in the power system on a five minute basis. Alternatively, a larger difference signals that the trading price associated with the 30 minute settlement outcome no longer provides a good signal of what is required on a five minute basis. That is, the 30 minute settlement is distorting the price signal for the efficient operation, use and investment in generation and demand response technologies in the NEM.

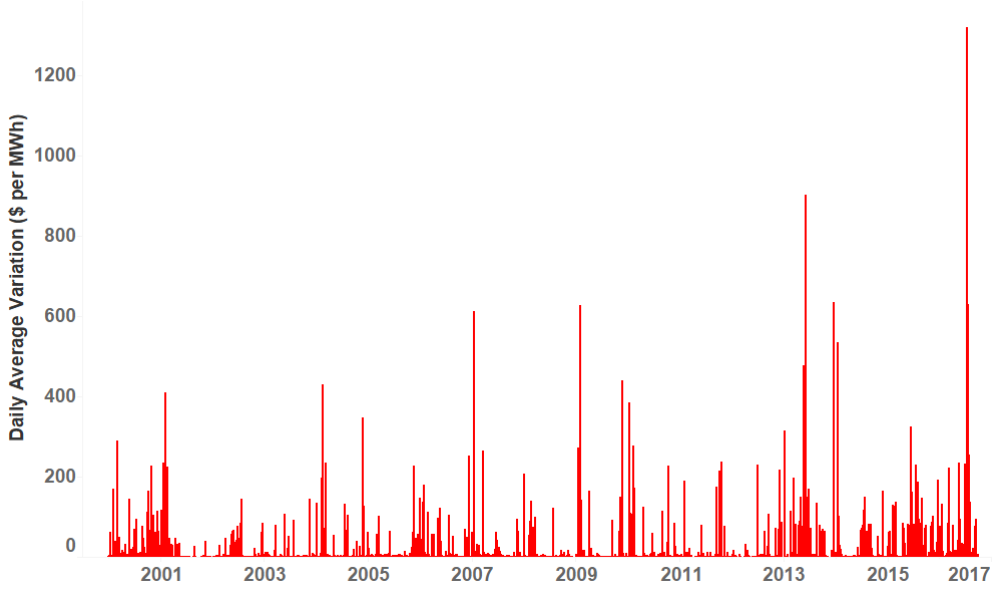
While the annual averaging used in the graphs in Figure 3.2 suppresses the magnitude of the variation that can be seen on a daily basis, it nevertheless highlights that:

- there are interregional differences between how effective the 30 minute trading price is as a signal for what is required on a five minute basis
- across the NEM since 2012 there appears to generally be an increasing trend of greater variation between the 30 minute trading price and the five minute dispatch price
- the increase in variation over time is greatest in Queensland and South Australia.

42 *Ibid*, p. 12.

Figure 3.3, reproduced from the Working Group Paper 1, examines South Australia more closely – the state that along with Queensland exhibits increasing variation over time. [43]

Figure 3.3 Daily average variation (SA, 2000 to 2016)

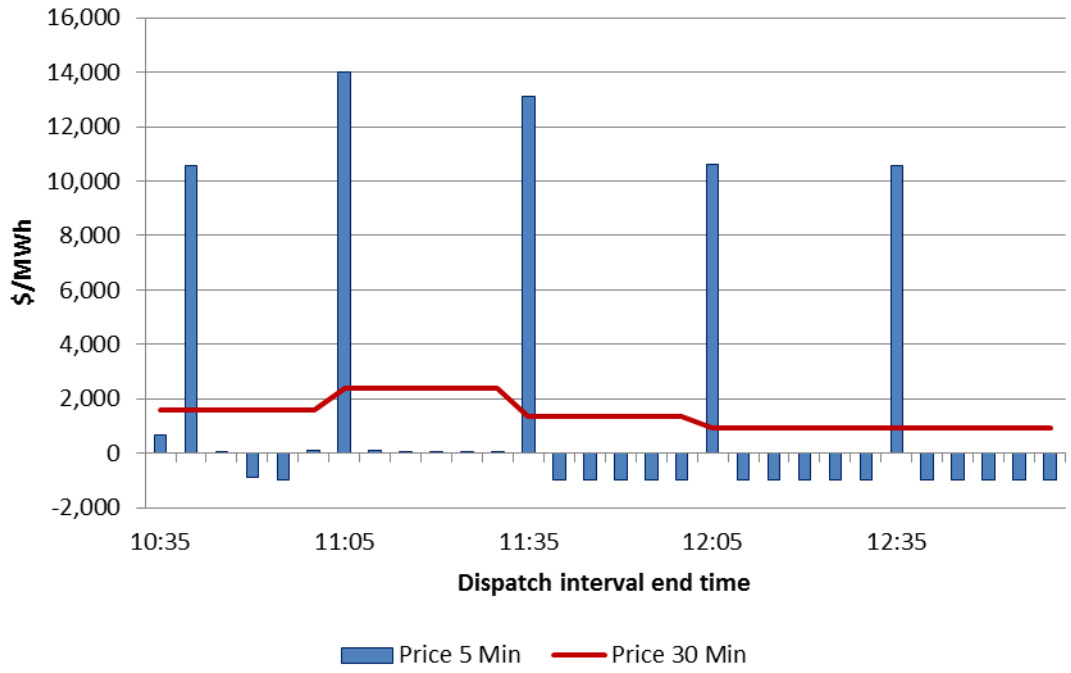


This highlights the magnitude of the average daily variation for South Australia. The chart removes the smoothing impact of the annual averaging in Figure 3.2 and shows that the daily average variation can be extremely high. For example, the maximum daily average variation is over $1,200/MWh. There are also many instances where the daily variation is above $100/MWh. This variation suggests there is often a significant difference between the price that a participant bids, and the final price that they actually receive under 30 minute settlement. This variation calls into question the effectiveness of the incentives provided by five minute prices under the existing 30 minute settlement framework.

Figure 3.4 below illustrates the type of incentive identified in section 3.3.1 that arises from the distorted price signal that the mismatch of dispatch and settlement creates. The chart compares the five trading intervals from 10.30am to 1.00pm on Tuesday 21 March 2017 in South Australia. It demonstrates how high prices in the first or second dispatch interval can lead to rebidding at a low or negative price (below short run marginal cost), as generators seek to pile in and share the benefit of the high price event. The variation in the five minute dispatch price serves to demonstrate how the outcome under 30 minute settlement, does not reflect the physical needs of the power system.

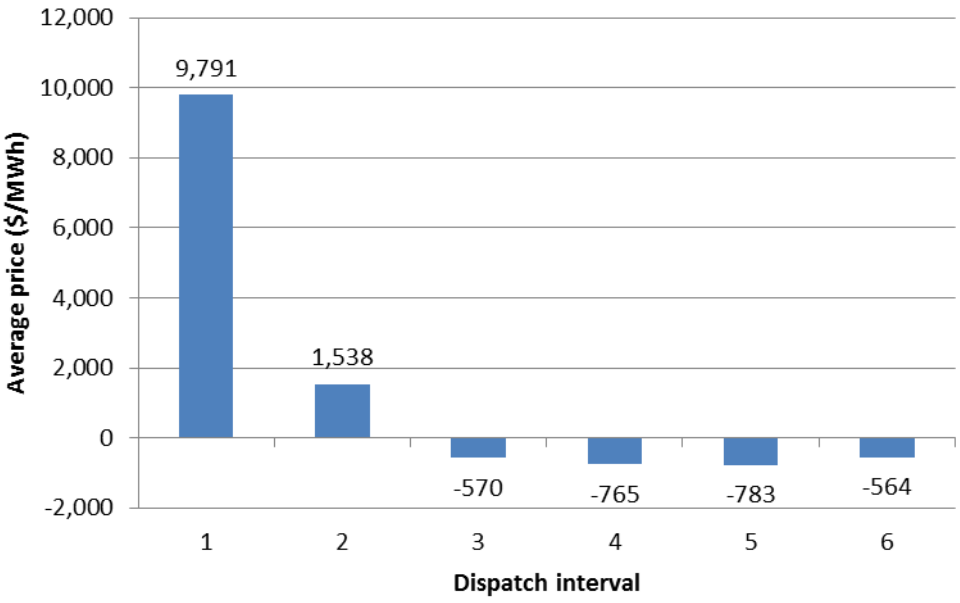
43 Australian Energy Market Commission, Five minute settlement working group, Working paper No. 1, 12 October 2016, p. 11.

Figure 3.4 21 March 2017 South Australia prices



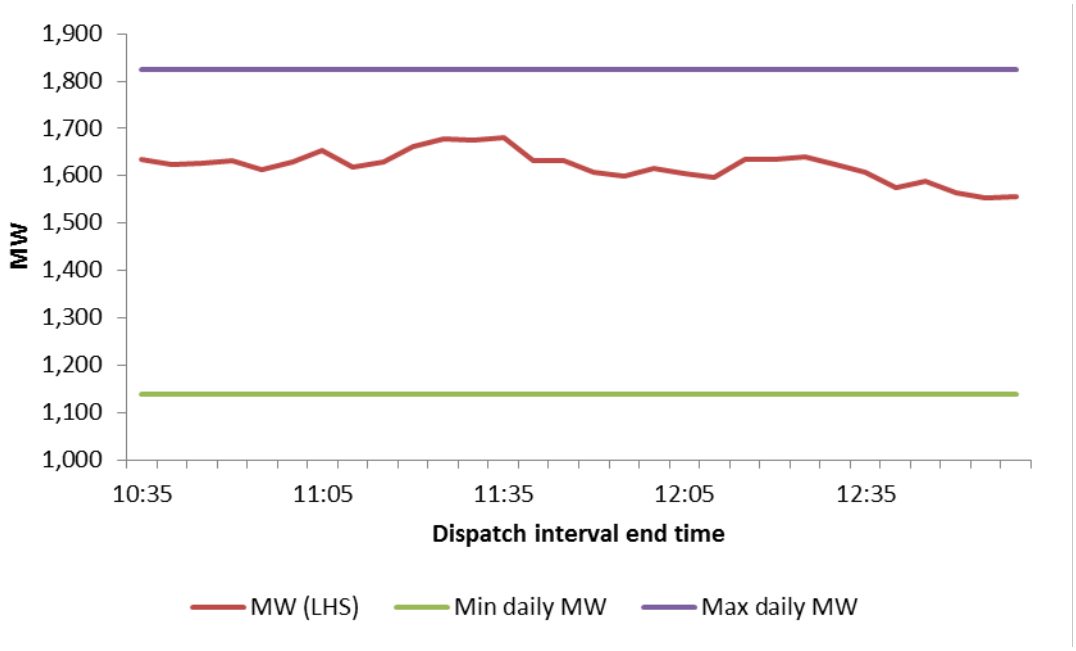
The outcome from 10:30am to 1:00pm on Tuesday 21 March 2017 in South Australia is highlighted in further detail in Figure 3.5. This shows the substantial difference in the average price in the five minute dispatch intervals over the five half hour trading intervals. This appears attributable to whether the dispatch interval was the first or second in the trading interval or a later dispatch interval. As noted in section 3.3.1 this bidding behaviour has the potential to significantly distort operational, usage and investment incentives, creating productive, allocative, and investment inefficiency. It is difficult to reconcile a framework that contributes to such behaviour as being consistent with the NEO.

Figure 3.5 21 March 2017 South Australia average dispatch interval prices



The example in Figure 3.4 shows how the pattern of dispatch interval offers under 30 minute settlement, can differ significantly from offers under five minute settlement, especially at times of high prices. The Figure 3.4 dispatch prices reflect a particular pattern of offers under 30 minute settlement that appear aimed at sharing in early dispatch interval high prices. This incentive would not exist under five minute settlement. It seems reasonable to expect that under five minute settlement, offers over this two-and-a-half-hour period would not have resulted in the same extreme variability in dispatch interval prices. This is especially the case given there was actually very little change in demand over this period. Figure 3.6 shows there was minimum demand of 1,553MW and a maximum of 1,681MW over this period. The chart also shows that the minimum for the day was 1,139 MW and the maximum for the day was 1,824 MW.

Figure 3.6 21 March 2017 South Australia demand



In this context it is worth noting that in a practical sense, five minute dispatch intervals are not independent of each other. Physical limitations of generation plant will impact on the change in megawatts offered by generators from dispatch interval to dispatch interval. Further, it is reasonable to expect that the actual demand and price achieved in the current dispatch interval, together with information from pre-dispatch, will be used to inform participants' decision making as to what volume and price to offer in future dispatch intervals.

There appears currently to be evidence in the NEM that distortions in price signals from 30 minute settlement are increasing and can be material. This is especially the case during periods of high prices, which there have been more of recently in the NEM. It is from these high price periods that generators typically receive a disproportionate amount of their annual spot market revenue. As such, 30 minute settlement is likely to be incentivising behaviour that is leading to operational, use and investment decisions that are inefficient. The next section assesses whether the issues highlighted with 30 minute settlement are likely to become worse over time.

Question 2 Understanding the inefficiencies

(a) How material are the price signal inefficiencies under 30 minute settlement and are there other data or data sources that would enable this issue to be more comprehensively addressed?

(b) What extent would a move to five minute settlement address inefficiency in price signals from 30 minute settlements?

(c) Are there any other inefficiencies that should be considered?

3.3.3 NEM design, generation mix, and investment requirement

The NEM is in the midst of a significant transition. A number of existing features of the NEM will influence the materiality of the problem associated with the existing 30 minute settlement, and the benefits associated with the proposed rule change. The particular features are:

- a wholesale electricity market established under the NEL structured as a gross pool market with no gate closure and a contract market developed by participants to manage the risk of price variation in the wholesale spot market
- the increasing levels of intermittent generation in the current generation mix of the NEM
- the age of the existing thermal generation fleet in the NEM.

The problems with 30 minute settlement are likely to be more material where the benefit from having an improved price signal is greater. For example, this will be the case where the price signal is needed to provide incentives for on-going efficient investment. That is, the combination of a gross pool market with no gate closure, an increasing need for new flexible generation to support intermittent generation in the NEM, and an ageing generation fleet in need of investment, all enhance the benefits of aligning dispatch and settlement. These factors would increase the materiality of the proposed rule change.

NEM design

The benefits of aligning dispatch and settlement have been acknowledged by a range of international energy market authorities. For example, in a few overseas markets where dispatch and settlement are not aligned – some US markets, New Zealand and Alberta – regulators and market bodies are either in the process of aligning or recognise the merit in doing so. For example:

- the United States Federal Energy Regulatory Commission (FERC) in September 2016 ruled that all system operators under its jurisdiction must settle energy in their real-time markets at the same interval that those markets are dispatched (i.e. five minute settlement)[44]
- the New Zealand Electricity Authority has noted that aligned dispatch and settlement interval would be the ideal market design[45]
- aligning dispatch and settlement intervals has also been discussed by the Alberta Electric System Operator.[46]

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44 FERC, *Settlement Intervals and Shortage Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators, Docket No. RM15-24-000*, 16 June 2016, http://www.ferc.gov/whats-new/comm-meet/2016/061616/E-2.pdf.

45 New Zealand Electricity Authority, *Assessment of real-time pricing options*, Information paper, 12 April 2016, p. 16, https://www.ea.govt.nz/dmsdocument/20599.

The NEM is a compulsory participation gross pool wholesale electricity market with no gate closure. Supporting the wholesale electricity market is a contract market, with optional participation. The contract market plays a crucial role as it reduces price uncertainty for generators, retailers, major industry, and consumers of electricity. By providing generators a degree of revenue certainty it allows them to manage risk, secure finance and provides signals for on-going investment in generation capacity. For retailers, contracts provide for security of supply to deliver price stability for consumers. It allows them to secure financing for their own operations.

Australia is unlike many overseas wholesale electricity markets, in that there are no separate capacity payments. All generation is required to be settled through the market at the spot price, and the dispatch price provides the signal for parties to negotiate contracts to enable efficient investment in generation capacity. The contracts market in the NEM is the effective market-based mechanism for investment in generation capacity. In those markets with capacity payments, the energy-related price signals tend to provide incentives for signalling short-term productive efficiency, in terms of dispatching the lowest marginal cost plant to satisfy a given level of demand. While energy-related price signals may provide a signal for the type of investment required in generation, the capacity payments tend to signal the need for investment in generation capacity over time.

In jurisdictions with a capacity market, the impact of having a distorted price signal through the mismatch of dispatch and settlement is less significant than might otherwise be the case. Investment is still incentivised through capacity payments. Nevertheless, jurisdictions, such as the US that have capacity markets in place, have still indicated there are significant benefits from moving to aligning dispatch and settlement at five minutes. Given the greater importance of the role of price in the NEM, where it provides a signal for efficient dispatch of plant and incentives to contract to undertake efficient investment, it would be expected that any benefits associated with aligning dispatch and settlement would be far more substantive.

The NEM also has no gate closure, which means volume rebids can be made up until the start of the processing for the relevant dispatch interval. It enables market participants in the NEM to take advantage of the availability of more accurate information on likely demand and prices as the dispatch interval gets closer. This allows them to better manage their participation in the market and can increase market efficiency. It is not a feature of a number of overseas markets, including the US electricity market.

However, the absence of gate closure also provides the ability for the type of late rebidding outlined in Section 3.3.1 and discussed further in Section 3.3.4. The incentive for such rebidding is likely to be higher under 30 minute settlement and significantly lower under five minute settlement. This further reinforces the greater benefits that are likely to be realised from aligning dispatch and settlement at five minutes in the NEM.

46 The Brattle Group, *International Review of Demand Response Mechanisms*, prepared for the AEMC, October 2015, p. 36.

Increased intermittent generation

The NEM is currently experiencing a period where there is rapid technological change. In Australia, and worldwide, there has been the retirement of synchronous thermal generators, and increases in penetration of intermittent generation, such wind and solar. This has occurred at both a utility-scale and in the case of embedded distributed generation. The NEM now has around 9 GW of renewable energy generation, comprised of nearly 4 GW of wind and over 5 GW of solar PV.[47]

The presence of increasing amounts of intermittent renewable generation creates both the need for, and the opportunity for, investment in flexible generation and demand response technology. This generation and demand response will be required to respond in real-time to variations in intermittent generation. It will contribute to resilience of the NEM, facilitating reliability and security of the power system for the next decade and beyond.

The need to transform the system as a whole with intermittent renewable generation has been highlighted by the International Energy Agency, which has stated:[48]

> "The challenges and opportunities of variable renewable energy (VRE) integration lie not only with VRE technologies themselves, but also with other system components. Consequently, a system-wide approach to integration is required. In short, integration of VRE is not simply about adding VRE to "business as usual", but transforming the system as a whole."

Similarly, Michael Hogan from the Regulatory Assistance Project (a multinational clean energy think-tank) noted in a recent paper:[49]

> "…a growing share of variable renewable resources increases the value of flexibility elsewhere in the system, value that can only be seen clearly in prices reflecting real-time conditions in the wholesale energy market."

Given the changes to the current generation mix in the NEM there is a need for a more efficient real-time price signal. This will create the right incentives for the required investment to occur in flexible generation and demand-side technologies. The increasing level of intermittent generation, a trend which is expected to continue in future, therefore increases the materiality of the problem associated with 30 minute settlement in the NEM. Similarly, it makes the alignment of dispatch and settlement more important and material.

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47 Wind generation see: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information. Roof top solar see: http://pv-map.apvi.org.au/analyses.

48 International Energy Agency, *The Power of Transformation – Wind, Sun and the Economics of Flexible Power System*, 2014, foreword.

49 M. Hogan, Follow the missing money: ensuring reliability at least cost to consumers in the transition to a low-carbon power system, *The Electricity Journal 30*, 2017, p. 55.

The existing generation mix and investment

In the next decade over 45 per cent of the existing electricity generation plants in the NEM will be at least 40 years old. It is likely that significant new investment will be required in the short-to-medium term to either upgrade or replace this infrastructure.

The potential magnitude of the investments is evidenced from the fact that, at a high level:

- the value of electricity settlements within the NEM are around $10 billion per annum
- estimated replacement cost of NEM generation assets are in the order of $130 billion[50]
- estimated replacement cost of NEM network assets are in the order of $120 billion.[51]

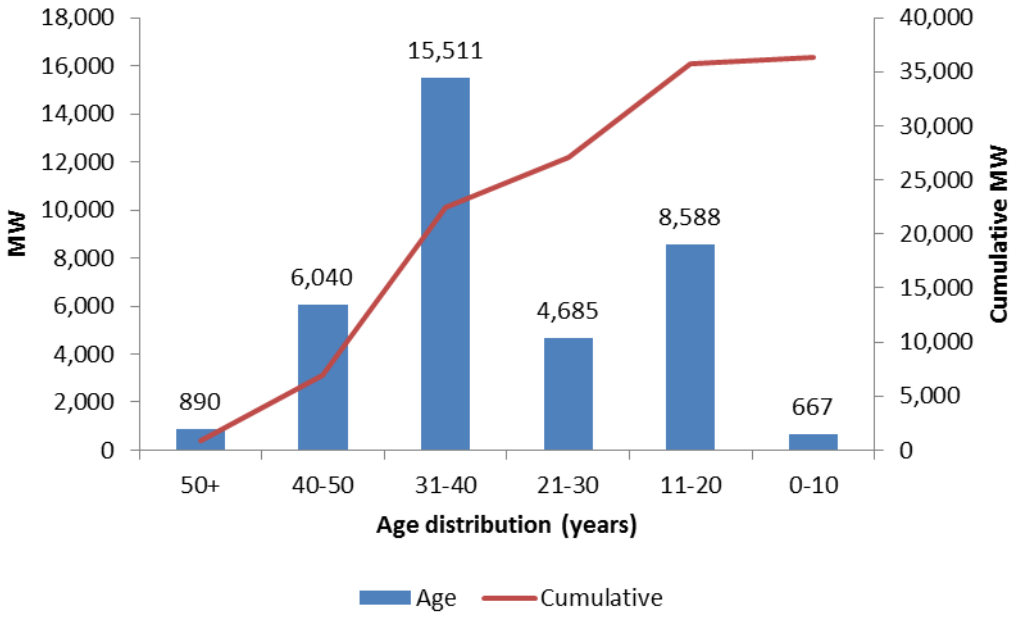
Taken together, the total replacement cost for NEM assets is estimated at a quarter of a trillion dollars or over $10,000 for every person in Australia.

The age distribution of existing thermal generation plant in the NEM suggests there will also be significant age-related generation plant retirements in the short-to-medium term. This is unless a very significant capital renewal plan is implemented for the existing fleet. Figure 3.7 presents the age distribution of existing thermal generation plant in the NEM.

50 This estimate is based on 45GW of capacity with an average replacement cost of $2.9 million/MW.

51 This estimate is based on the aggregate regulated depreciated asset values of around $80 billion and an assumption of two thirds life expired.

Figure 3.7 Age distribution of NEM thermal generation plant



Data source: AEMC.

The above figure shows there is nearly 7,000 MW of thermal generation capacity that is over 40 years of age and more than 15,000 MW between 31 and 40 years old. The design life of thermal generation plants tends to be 30 to 40 years depending on the technology. While in practice thermal generation plants can last significantly longer, the decision for the owners is often whether to maintain the existing plant through further renewal investment, or undertake investment in a new plant.

With these plants nearing the end of their design life, there is an almost immediate need for between $10 billion and $28 billion in investment to upgrade or replace potentially end of life thermal generation fleet. If thermal generation plant older than 30 years is also included, where replacement or upgrade planning should already be underway, then the medium-term investment need grows to between $34 billion and $90 billion.[52] The results in Figure 3.1 are summarised in Table 3.1.

52 The actual cost will vary depending on the technology adopted. The lower cost estimates are consistent with gas turbine costs of around $1.5 million/MW. The high costs reflect coal generation at around $4 million/ MW. It is likely that renewable generation with some level of energy storage will fall within this cost range. The use of gas and coal plant costs should be considered illustrative only and does not reflect a view on the preferred technology.

Table 3.2 Potential generation investment to replace retiring plant

Age category	Cumulative MW	Cost Low ($B)	Cost High ($B)
50+	890	1	4
40-50	6,930	10	28
31-40	22,441	34	90

The pressure for changes in the electricity supply system is complicated by the large historic investment in long-life infrastructure and the requirement to recover this investment over the life of the assets. One impact is that historically, the opportunity to implement new technologies has arisen infrequently in the NEM.

There are now new technologies emerging and rolling out commercially in much shorter timeframes This is evidenced on the demand side by the continued growth of household solar photo-voltaic (PV) systems, which currently amounts to nearly 6 GW of intermittent renewable capacity across Australia, and the recent trend of associated behind the meter battery storage investment.[53]

The need for efficient price signals becomes increasingly important in the NEM as it is faced with such things as, age-based retirements, changing digital technologies that allow for more active demand-side participation (see section 4.5), and increasing levels of generation by consumers. Price signals will directly influence the type of technology installed, and the scale and location of investments responding to changing demand conditions. In this environment the materiality of the problem of 30 minute settlement will be greater. Conversely, the benefits of aligning dispatch and settlement at five minutes and providing an improved price signal, will be more significant.

Question 3 Impact of an evolving market

How does an aging generation fleet together with rapidly evolving digital technologies and the increasing role of intermittent generation affect the prospects of five minute settlement as compared with 30 minute settlement?

3.3.4 Late rebidding

The analysis in Working Group Paper 1, reproduced in section 3.3.2, highlights the amount of dispatch interval price variation exists within a trading interval. To the extent this is due to late rebidding, discussed in section 3.3.1, submissions have argued the Bidding in Good Faith rule change in place from 1 July 2016 should be given time to prove its effectiveness.[54] For example, AGL stated:[55]

53 Solar PV installations found at http://pv-map.apvi.org.au/analyses.

54 AEMC, *Bidding in Good Faith*, final determination, 10 December 2015.

55 AGL, consultation paper submission, p. 3.

> "AGL considers that the Bidding in Good Faith rule could be far more effective in addressing the bidding behaviour Sun Metals is concerned about. In any case, the new rebidding rule should be allowed to operate for a period of time before alternative mechanisms to target bidding behaviour are considered."

However, this does not address other behaviour that may arise as a result of the perverse incentives implicit in 30 minute settlement.

For example, the incentive to bid below marginal cost over successive periods is described and highlighted in sections 3.3.1 and 3.3.2. As outlined earlier, this may occur where an early dispatch interval price spike encourages piling in behaviour and participants bid in at the market floor price or some other value lower than marginal cost. Under 30 minute settlement this maximises their share of the trading interval settlement value. This behaviour though is unlikely to result in a productively efficient outcome. Generators are no longer responding to the five minute dispatch price, but the expected price over the 30 minute settlement period. This undermines the role of spot market design, as they are generating at a time when it is not necessarily valued by the power system. Further, 30 minute settlement reduces the benefit of an allocatively efficient demand response to a high price event.

Similarly, 30 minute settlement provides perverse incentives for generators to maximise energy output in a trading interval where a high price event has occurred. For example, it encourages:

- late rebidding to create a late price spike in a trading period
- non-conformance with dispatch instructions, to generate more when there is an early price spike
- generators to present themselves as less flexible than they actually are to avoid being ramped down, and so they can share the high price interval.

The Commission considers that the failure to align settlement and dispatch will continue to provide an on-going incentive for perverse behaviour.

While there may be less instances of the type of late rebidding that the Bidding in Good Faith rule change was designed to address, the Commission is of the view that there is sufficient evidence to suggest there are still a range of issues with rebidding. In particular, as section 4.4.2 highlights bidding appears to have shifted the price spikes from dispatch interval six to dispatch interval one. The potential inefficiencies that price spikes occurring in an early period create under 30 minute settlement was discussed in section 3.3.2 and highlighted in Figure 3.4. This type of behaviour will continue as long as there is a misalignment between dispatch and settlement periods.

The Commission considers that to the extent that five minute settlement reduces late rebidding and other perverse behaviour, it may also serve to improve pre-dispatch accuracy and create an environment where generator unit commitment decisions can be made more proactively.

Question 4 Bidding behaviour

What kinds of generator bidding behaviours could emerge under five minute settlement as compared with 30 minute settlement?

3.4 Commission's initial position

The Commission notes that there were pragmatic reasons for the adoption of differing dispatch and settlement periods at the start of the NEM. These constraints no longer apply as changes in metering and data processing technology have made five minute settlement a feasible option.

The Commission's initial position regarding the materiality of the problem identified by the rule change request is:

- There are strong in principle efficiency arguments for the alignment of the dispatch and settlement periods. The current arrangement creates incentives for generators that are not able to respond to the five minute price to bid prices below their marginal cost, generate at times when it not physically valued by the power system, and behave in a way that creates artificial volatility and risk in the NEM. It can even result in generation or load response that occurs up to 25 minutes after it is needed by the power system. The mismatch between dispatch and settlement can also be expected to stifle the operation of fast response technologies that can respond over a dispatch interval. As 30 minute settlement is not technology neutral, it creates poor incentives for investment and innovation in more flexible generation and demand response technologies over time.

- There is evidence in the NEM that the distortions in price signals from 30 minute settlement can be material, especially during periods of high prices. This is likely to be leading to operational, use, and investment decisions that are inefficient.

- The NEM design and current market conditions, mean that the materiality of distortion from 30 minute settlement is likely to be greater over time, and the benefits from having better price signals under five minute settlement will increase. These factors include:

  - the NEM being a compulsory participation gross pool market, which increases the importance of price in determining investment

  - the transition towards increasing intermittent generation, which means there is a need for investment in flexible technologies that can be operated in a way that balances the system, enhancing reliability and system security

  - the significant level of investment required over the next decade (possibly approaching $100 billion), which would benefit from an improved price signal.

- There is likely to be benefits associated with improving incentives for rebidding under five minute settlement.

At this stage, based on the above considerations the Commission is of the view that on balance there is a material problem with the existing 30 minute settlement regime that could be addressed through adoption of five minute settlement.

Question 5 Materiality of the problem

(a) What other issues are likely to be material in considering the introduction of five minute settlement?

(b) Is there other data or data sources that can better inform the analysis of the materiality of the problem with 30 minute settlement or the move to five minute settlement?

4 Impact on operation and investment

The analysis in Chapter 3 demonstrated that five minute settlement would present different incentives and risks in comparison to the current 30 minute settlement arrangements. Five minute settlement would provide an improved price signal that more accurately reflects the physical requirements of the power system. The extent of the economic benefits from implementing five minute settlement would depend on the ability of supply and demand-side participants to change their behaviour in response to the more granular five minute price signal. The potential benefits also be depend on whether five minute settlement would allow for workable hedging and risk management outcomes. These issues are explored in this chapter in the following sections:

- Summary of stakeholder views.
- Discussion of the ability of different technologies to respond to five minute prices.
- Analysis of the potential impact of five minute settlement on participants' hedging and risk management arrangements.
- Discussion of the incentives to invest in flexible technologies.

4.1 Sun Metals' view

Sun Metals noted that batteries, some loads and some transmission systems are capable of responding within a five minute period.[56]

4.2 Stakeholder views

There was a diverse range of views on the ability of existing and new technologies to respond to a five minute price signal. Generators and retailers were generally of the view that most existing supply and demand-side resources would not be able to respond.[57] Origin Energy submitted that the gains from implementing five minute settlement would be constrained by the limits of the existing generation fleet.[58] Other stakeholders suggested that five minute settlement would promote fast responding demand management and energy storage technologies, and that existing assets could be operated differently. The range of views are summarised below in the categories of existing thermal generators, demand-side response and energy storage.

56 Sun Metals' rule change request, p. 2.

57 E.g. ERM Power, consultation paper submission, p. 4.

58 Origin Energy, consultation paper submission, p. 3.

Existing thermal generators

Stakeholders identified that baseload and intermediate generators that are online are able to respond quickly if they are not at a capacity limit (i.e. minimum or maximum loading).[59] Aside from this, the focus for many stakeholders was on the capabilities of fast start generators. In the NEM, fast start generators are implicitly defined as generators that require less than 30 minutes from receiving a start instruction to reach minimum load, and can synchronise, reach minimum loading and shut down in less than 60 minutes.[60] This category includes OCGT, hydro and diesel generators.

Generators and retailers identified that most existing fast start generators are unable to respond within a five minute period.[61] On account of this, it was widely considered that the rule change would have a negative impact on fast start generators. A key concern was that generators that require more than five minutes to respond from rest would have no certainty of the price that they will receive when they are dispatched.[62]

AGL Energy reasoned that the 30 minute settlement period incentivises fast start generators to turn on as they can be guaranteed to make a profit if a price spike has been sufficiently high. Generators then remain online for some period of time as their costs of starting up have become sunk. AGL Energy submitted that this response increases the level of competition amongst generators and reduces volatility.[63] EnergyAustralia referenced the same scenario, noting that responses from fast start generators can limit consecutive dispatch intervals with very high prices.[64] ERM Power suggested that this response from peaking generators provides "price relief", which would not occur if the rule change was to be made.[65]

Generators and retailers were of the view that the inability of fast start generators to respond within five minutes, and the loss of price assurance that this would entail, would limit their ability to sell hedging contracts. Engie noted that only those who can respond within five minutes would be able to appropriately manage their price and volume risks in the spot market.[66] ERM Power submitted that fast start generators may no longer sell contracts, or would need to run at low loading levels so they could respond quickly to price spikes. The cost of "cap" contracts would rise as a result of less availability and greater risks.[67] This was a view supported by Snowy Hydro. Snowy Hydro submitted that 30 minute settlement aids generators to manage spot pricing risks as a generator can increase its output to minimise its exposure on the

59 Stanwell, consultation paper submission, p. 4.

60 Clause 3.8.17(a) of the NER defines *slow start generating units* as generating units which are unable to synchronise and increase generation within 30 minutes of receiving an instruction from AEMO.

61 Consultation paper submissions: Engie, pp. 3-5; ERM Power, p. 3.

62 Engie, consultation paper submission, p. 4.

63 AGL Energy, consultation paper submission, p. 2.

64 EnergyAustralia, consultation paper submission, p. 3.

65 ERM Power, consultation paper submission, p. 1.

66 Engie, consultation paper submission, p. 3.

67 ERM Power, consultation paper submission, p. 4, p. 7.

contracts that it has sold, in the case of a price spike early in a 30 minute trading interval.[68]

Generators and retailers submitted that, on account of the above, fast start generators would face a diminished incentive to remain in the NEM under five minute settlement.[69]AGL Energy suggested that other generators might create "random five minute spikes at any point" that fast start generators are not able to catch, forcing them to exit the market.[70] The AEC was concerned that five minute settlement would change the economic sustainability of generators that support peak demand for longer than five minutes.[71] Engie also considered that this would be a poor outcome as fast start generators are increasingly needed to fill the gaps left by intermittent generation sources.[72]

A contrasting view was provided by Wärtsilä. Wärtsilä acknowledged that it would only be expedient for OCGT generators to start if consecutive price spikes are expected. However, it submitted that this would motivate generators to improve their forecasting accuracy so that they can start their plant ahead of a price spike.[73] Wärtsilä also noted that internal combustion diesel generators have characteristics that would be favourable in a market with five minute settlement.

Demand-side response

Stakeholders were divided on the issue of whether five minute settlement would be advantageous for those engaging in demand-side response, which can involve load curtailment, load cycling, fuel substitution and switching to on-site generation.

ERM Power submitted that only a small number of large users in the NEM are capable of responding within five minutes. A manual response is often required before load reductions can occur.[74] This position was supported by Major Energy Users, who submitted that very few large users can adjust their demand at short notice, and those that can may not elect to do so for reasons outside of the electricity market.[75] EnergyAustralia noted that workplace practices and processes may not be sufficiently flexible to provide a rapid response of short durations.[76] Similarly, ERM Power questioned whether large users would want to engage in multiple five minute responses in one day, or responses in consecutive days.[77] Origin Energy was of the

68 Snowy Hydro, consultation paper submission, p. 3.

69 Consultation paper submissions: Engie, p. 5; ERM Power, p. 2.

70 AGL, consultation paper submission, p. 2.

71 Australian Energy Council, consultation paper submission, p.2.

72 Engie, consultation paper submission, p. 5.

73 Wärtsilä, consultation paper submission, p. 8.

74 ERM Power, consultation paper submission, p. 4.

75 Major Energy Users, consultation paper submission, p. 4.

76 EnergyAustralia, consultation paper submission, p. 2.

77 ERM Power, consultation paper submission, p. 5.

view that customers generally do not have a strong desire or capacity to participate in the wholesale market, but this may change as battery storage technology develops.[78]

The AEC, ERM Power and Snowy Hydro submitted that large users engaging in demand response would be disadvantaged in a similar way as fast start generators.[79] Snowy Hydro noted that if a price spike occurs early in a 30 minute trading interval, a load has the option to reduce consumption to lower its overall trading interval cost. This would not be possible under five minute settlement.[80] The AEC suggested that five minute settlement would suppress the willingness of slower demand response providers that would address longer duration peaks.[81] ERM Power was of the view that five minute settlement would make demand response less likely and that this would reduce market efficiency.[82]

Other stakeholders considered that five minute settlement would be beneficial for those seeking to engage in demand response. AEMO suggested that industrial processes should be able to tolerate interruption, however further investigations may be required as to how different loads react.[83] The Australian Energy Storage Alliance (AESA) submitted that five minute settlement would be more viable for demand response.[84] The Australia Institute considered that if demand-side participants were to be fully rewarded for five or 10 minute responses, this would encourage greater demand-side participation.[85] Similarly, Intelligent Energy Systems was of the view that five minute settlement would increase returns for those engaging in demand response, so must encourage a greater response.[86]

Energy Consumers Australia considered that five minute settlement would send stronger signals about the adoption of new energy services, such as direct demand control and demand response. It submitted that a dynamic services market is firmly in the long term interests of energy consumers.[87]

Energy storage

Stakeholders generally acknowledged that batteries are capable of providing a very fast response. Reposit noted that batteries tend to have very fast, bi-directional capability, but sometimes they cannot sustain this behaviour (i.e. delivering or

78 Origin Energy, consultation paper submission, p. 3.

79 Consultation paper submissions: Australian Energy Council, p. 2; ERM Power, consultation paper submission, p. 4; Snowy Hydro, p. 3.

80 Snowy Hydro, consultation paper submission, p.3.

81 Australian Energy Council, consultation paper submission, p. 3.

82 ERM Power, consultation paper submission, p. 5.

83 AEMO, consultation paper submission, pp. 2-3.

84 Australian Energy Storage Alliance, consultation paper submission, p. 4.

85 The Australia Institute, consultation paper submission, p. 1.

86 Intelligent Energy Systems, consultation paper submission, p. 2.

87 Energy Consumers Australia, consultation paper submission, p. 4.

consuming energy) for very long.[88] ZEN Energy submitted that modern batteries with state-of-the-art software platforms can respond in a nanosecond to variations in supply and demand for electricity.[89] ERM Power was also of the view that battery storage could dispatch into the market almost instantaneously, but that it is currently a niche product operating at a small scale. ERM Power considers that it is uncertain when battery storage will be able to operate instantaneously on a large enough scale to respond to price spikes.[90]

Stakeholders involved in the manufacture and deployment of batteries were of the view that five minute settlement would be beneficial for energy storage.[91] Ecoult noted that 30 minute settlement presents risks for battery owners that provide a few minutes of power during a price spikes. It considered that the proposed rule change would likely increase applications where energy storage is the most cost-effective solution to managing grid variability and peak pricing.[92] Similarly, ZEN Energy submitted that 30 minute pricing reduces the incentives for introducing rapid response battery storage technologies.[93]

Origin Energy provided a contrasting view, submitting that it does not believe that the current arrangements impede the deployment and use of battery storage as a consumption management device.[94]

4.3 Analysis: Responsiveness of generation and load

The in principle argument for five minute settlement is that it would provide for better alignment between the physical requirements of the power system and the financial incentives of market participants. It would therefore provide an improved price signal for efficient operation, use and investment decisions, as described in Chapter 3. The magnitude of the benefits arising from the rule change depends upon the ability of market participants to change their behaviour. Material changes in behaviour would suggest the potential for material efficiency gains for the market. Conversely, if participants are unable to change their behaviour in response to five minute settlement, there may be limited benefit from making such a change.

The following sections explore potential changes in the operation of existing assets and possible new investments that could provide flexible responses to five minute settlement.

88 Reposit Power, consultation paper submission, p. 1.

89 ZEN Energy, consultation paper submission, p. 2. A nanosecond is one billionth of a second, or $1*10^{-9}$ seconds.

90 ERM Power, consultation paper submission, p. 4.

91 Consultation paper submissions: Australian Energy Storage Alliance; Ecoult; Reposit Power; ZEN Energy.

92 Ecoult, consultation paper submission, p. 1.

93 ZEN Energy, consultation paper submission, p. 1.

94 Origin Energy, consultation paper submission, p. 3.

4.3.1 Existing participants

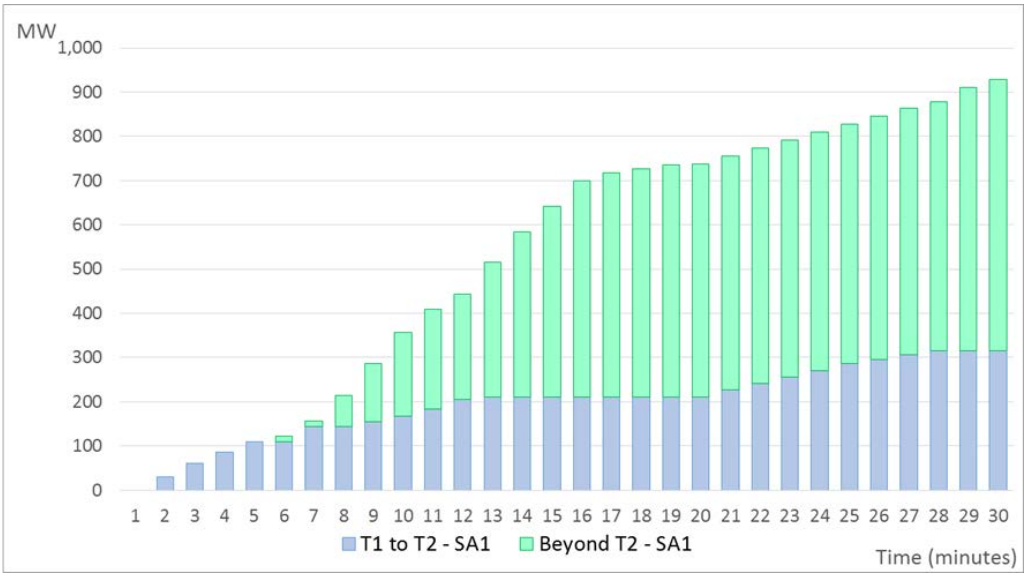
Existing generators, loads and storage operators could change the way in which they operate to maximise their revenue under five minute settlement. A summary of the potential responses from these categories of participants are provided below.

Responding from rest

The responsiveness of generators can be observed through market data describing the ability of generators to respond from rest and when they are already running. One way of observing responsiveness from rest is through the fast start inflexibility profiles that fast start generators submit as a component of their offers and rebids.[95] When generators are online and running, responsiveness can be observed via ramp rates, and maximum and minimum output levels.

An indicative illustration of the potential response from rest can be observed by extracting the fast start profiles for all scheduled, fast start generators for a single day. Figure 4.1 below shows this analysis for all fast start generators in South Australia on a day in May 2016. It assumes that all fast start generators are offline and simultaneously receive a start instruction from AEMO. The generators are assumed to follow their fast start inflexibility profiles to their minimum output levels, than ramp at their specified ramp rates beyond this point. The latter is show in green and the former in blue. Figure 4.1 shows that in South Australia on the day of the analysis, 109 MW of capacity was available within a five minute period, increasing to 929 MW over the half hour.

Figure 4.1 Theoretical response from fast start plant in South Australia



The same analysis was undertaken for each NEM region and the corresponding charts are presented in Appendix 4.3 of Working Group Paper 1, which is available from the

95 Fast start inflexibility profiles have 5 parameters: minimum load, time to synchronise (T1), time to ramp to minimum load (T2), minimum time above minimum load (T3), and time to ramp down (T4). See: AEMO, *Fast-start Inflexibility Profile*, process description, October 2014.

Five Minute Settlement project page on the AEMC website.[96] This analysis is based on fast start profiles from a single day and ramp rates have been assumed at nameplate ratings. It does not include network or economic constraints, nor factor in the time for AEMO to send dispatch instructions. It may also underestimate the potential response of fast start plant as non-scheduled generators, many of which are reciprocating engines, are not included in the analysis.[97]

Notwithstanding these caveats, this analysis provides an indicative result that there is limited fast start capacity in the NEM that can respond from rest within a five minute period. In South Australia and Queensland there is a small amount of scheduled capacity that can provide energy within five minutes. In other regions, the potential responses from rest were in the order of six to 10 minutes, with no fast start generators capable of providing energy from rest within five minutes.

Ramping online plant

The other response that can be provided is from generators that are already online. This would typically include coal-fired generators, some combined-cycle gas turbine (CCGT), and fast start generators if they are already running. For this analysis, the historical ramping of scheduled generators was calculated by comparing, for every dispatch interval between January 2015 and December 2016, the difference in dispatch targets from the previous five minute interval.[98] The results show that generators demonstrate a range of ramping capabilities, which are generally dependant on the operating level at the start of the dispatch interval in question.

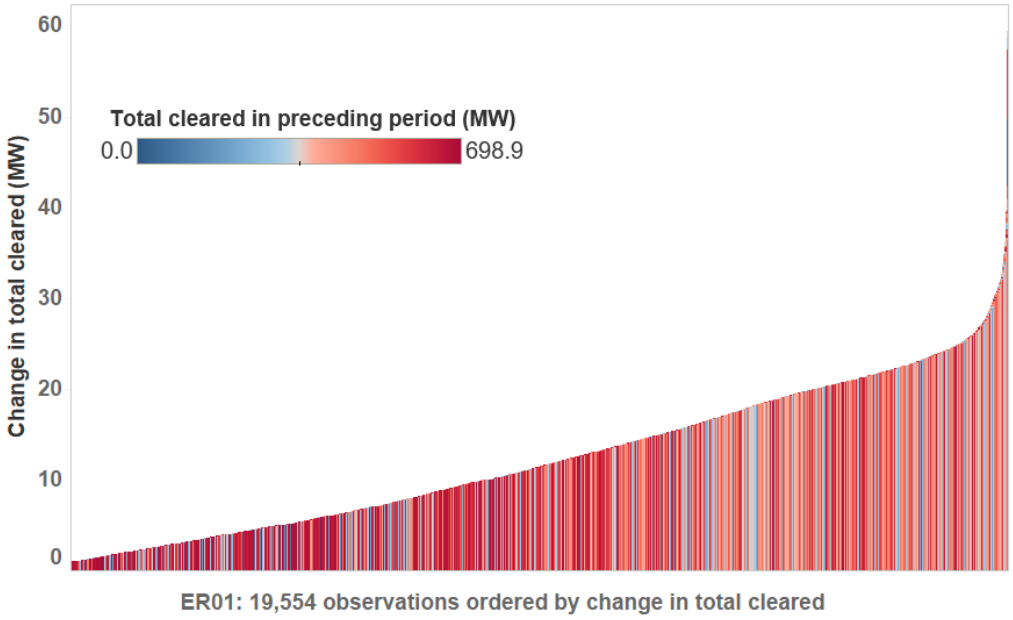
The following charts show the change in output in every dispatch interval when power output increased by more than 1 MW. The bars are sorted in ascending order and coloured based on the initial output at the start of the dispatch interval. Blue indicates an initial condition close to zero, while red indicates that the unit is close to full capacity. Figure 4.2 below shows that baseload coal-fired plant (e.g. Eraring) has historically not ramped very much over individual dispatch intervals. Most of the observations are red because Eraring is a baseload plant and ramping takes place between relatively high levels of output.

96 AEMC, *Five Minute Settlement Working Group: Working Paper No.1*, 12 October 2016, pp. 39-40.

97 AEMO registration data indicates that there is 740 MW of non-scheduled, reciprocating engine capacity in the NEM.

98 Differences in Total Cleared MW.

Figure 4.2 Historical five minute ramping of Eraring unit 1 (2016)



Hydro and gas-fired generators have demonstrated a wider range of ramping capability. The following figures for Tumut 3 (hydro) and Oakey unit 2 (OCGT) are provided as examples. In contract to Figure 4.2, there are more blue observations in these figures, reflecting the fact that more of the observed responses from these generators occur from rest, or relatively low output levels. In 2016, Tumut 3 often achieved changes in total cleared power of 250 MW between consecutive five minute dispatch intervals, and changes over 500 MW (corresponding with ~28 per cent of rated capacity) on some occasions.

Figure 4.3 Historical five minute ramping of Tumut 3 (2016)

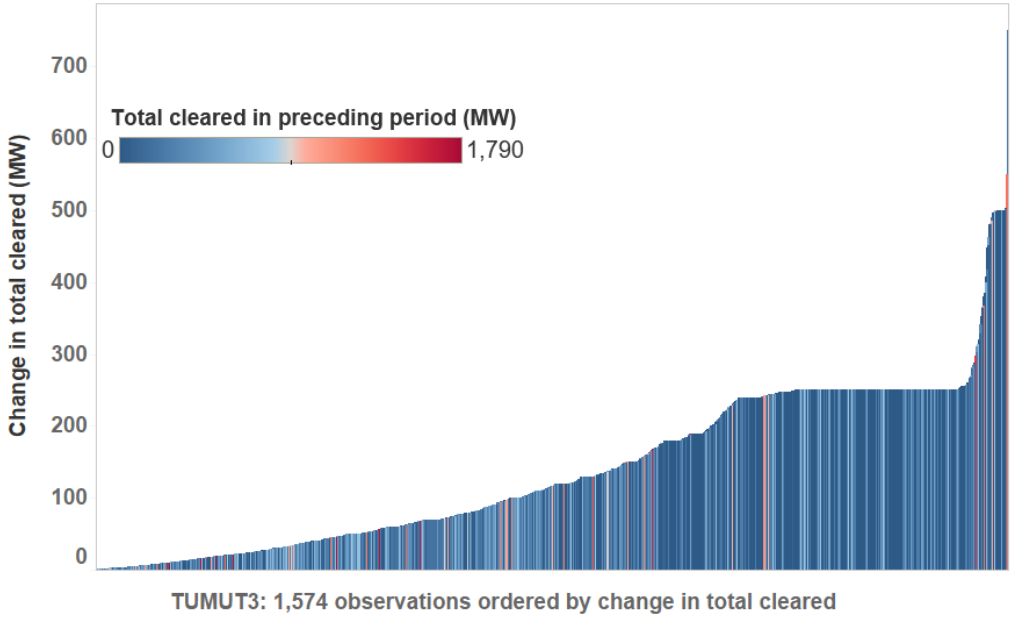


Figure 4.4 Historical five minute ramping of Oakey unit 2 (2016)

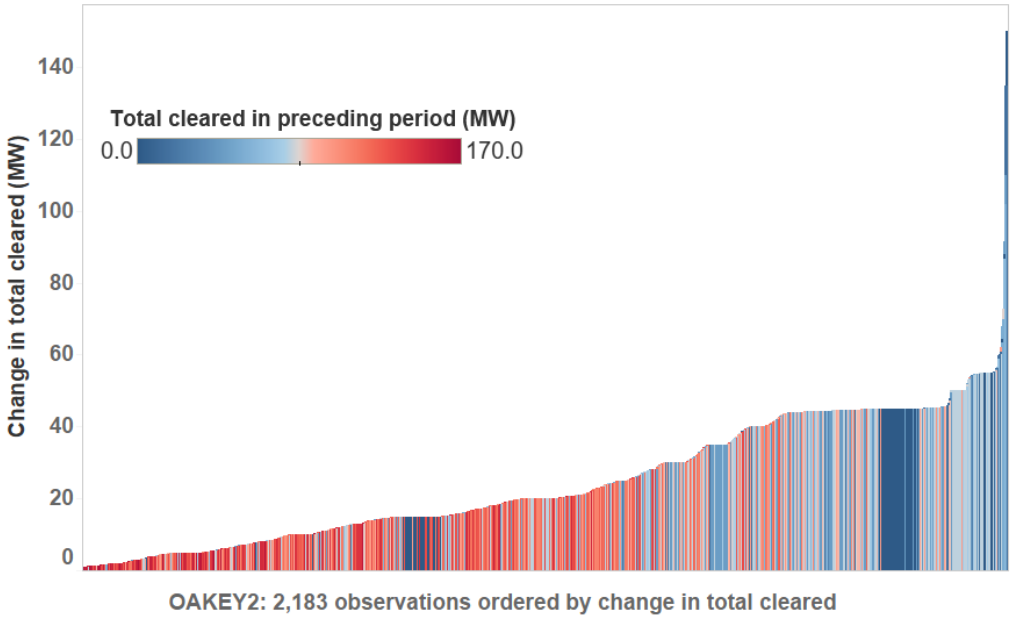
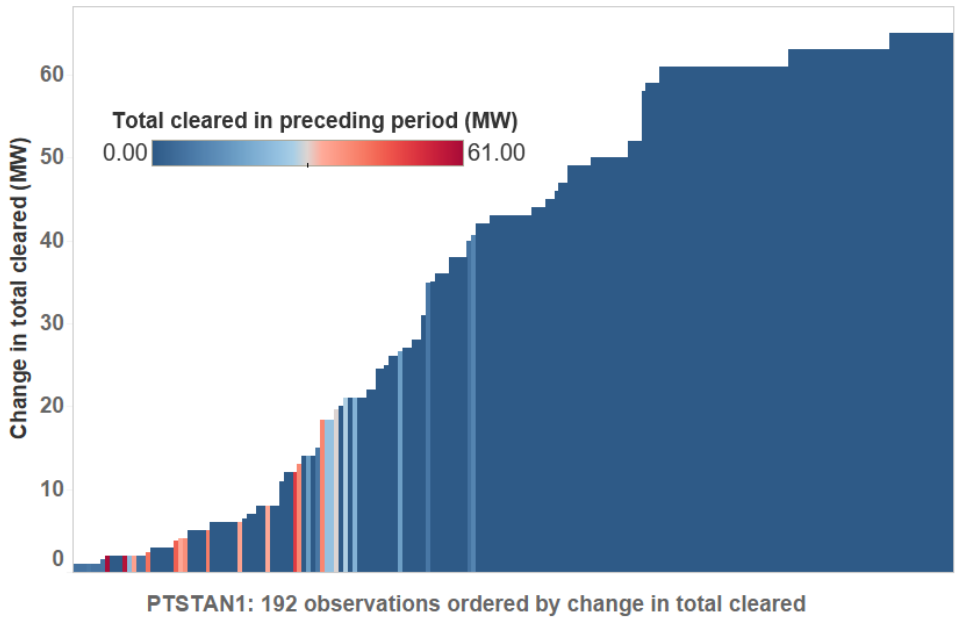


Figure 4.5 shows the same analysis for the diesel generator Port Stanvac. Much of the observed ramping is between zero and full output within individual dispatch intervals.

Figure 4.5 Historical five minute ramping of Port Stanvac (2016)



This analysis shows that responses in the hundreds of megawatts in five minute periods can be provided by existing generators in the NEM, though there may be additional costs associated with faster ramping. Another factor to consider is that generators are paid on the basis of energy provided to the market, rather than the output level that they achieve by the end of a dispatch interval. Scheduled generators are expected to ramp linearly between dispatch targets and are penalised through the cost recovery mechanism for regulation frequency control ancillary services (FCAS) if

they deviate from this trajectory. To avoid this penalty, a generator that responds from rest is effectively constrained to an average output for the dispatch interval of 50 per cent of the dispatch target.[99] In certain circumstances, it may be beneficial for a generator to deviate from the assumed linear trajectory as the additional wholesale market revenue is greater than the penalty. However, the way in which the cost recovery mechanism currently operates makes it difficult for generators to make this trade-off.[100]

The figures above are instructive of the historical ramping ability of these individual generating units. Further analysis has been undertaken to assess the aggregate ramping ability of all scheduled generating units. The aggregate, regional ramping capability was calculated for every five minute period in 2016, then averaged for each five minute period of the day. This analysis uses the same data as above (i.e. changes in the dispatch targets of scheduled generators from one dispatch interval to the next).

In each dispatch interval, each unit's ramping potential was calculated as:

- the minimum of: its maximum ramp rate and its available, unused generation, or
- zero if a unit is not generating.

The maximum ramp rate was calculated as the five minute ramp that the unit achieved or exceeded for over 2 hours' worth of dispatch intervals between January 2015 and December 2016. The ramping potential for all generators in a region was summed together for each dispatch interval (i.e. all 7:00, all 7:05, etc.), then divided by the number of days in the period analysed (and therefore the number of instances of each dispatch interval). The value for each five minute period is an average, so changes between consecutive five minute periods represent average changes in regional camping capability.

The results for New South Wales and South Australia are presented below in Figure 4.6 and Figure 4.7. The same charts for the other jurisdictions are presented in Appendix 4.4 of Working Group Paper 1.[101] These are stacked area charts where the ramping capacity is coloured by the fuel source of the generators providing the ability to ramp. The charts show that in 2016 there was, on average, hundreds of megawatts of ramping capability in each dispatch interval in each region of the NEM. In New South Wales there was consistently around 650 MW of capacity that could have been provided

99 E.g. A 100 MW receives a dispatch target to ramp from 0 MW to 100 MW. Assuming it reaches 100 MW by the end of the five minute period, it will have delivered (5/60)/2*100 MW = 4.17 MWh of energy, which is equivalent to a 50 MW unit running at 50 MW for five minutes. In practice, the energy delivered would be lower than this as dispatch instructions are not received by generators until 15-50 seconds after the dispatch interval has commenced.

100 Deviations from the linear trajectory are calculated on a four second basis and then averaged over each five minute period to generate five 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.

101 AEMC, *Five Minute Settlement Working Group: Working Paper No.1*, 12 October 2016, pp. 41-42.

within five minutes, compared to 200 MW in South Australia, 500 MW in Queensland, 350 MW in Tasmania and 300 MW in Victoria.

Figure 4.6 Ramping capacity in New South Wales in 2016, coloured by fuel type

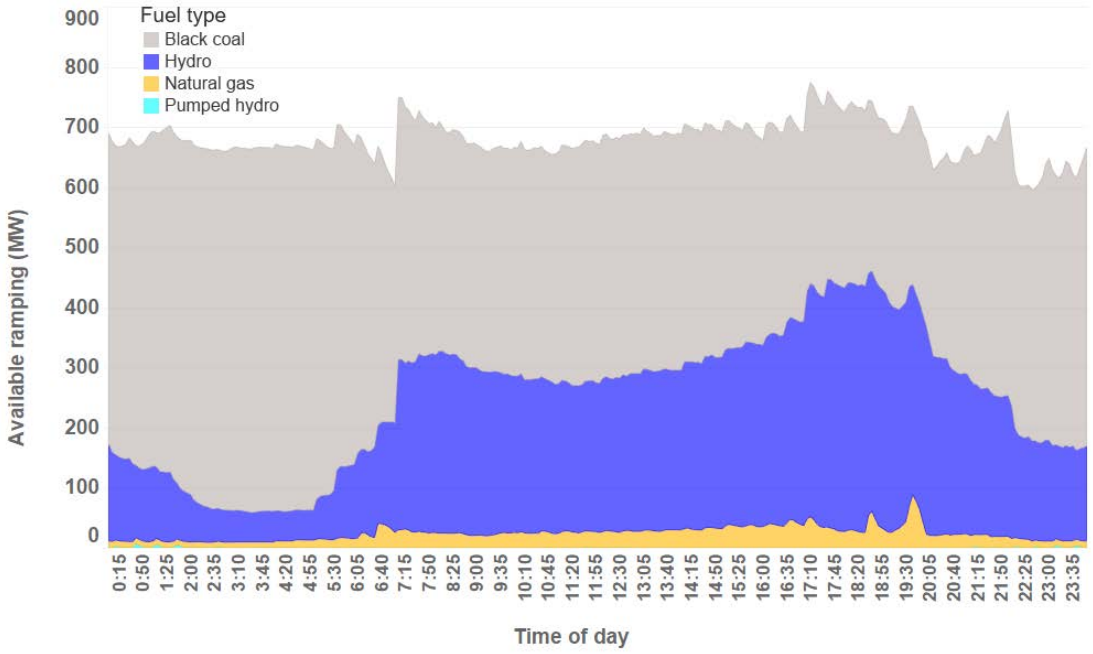
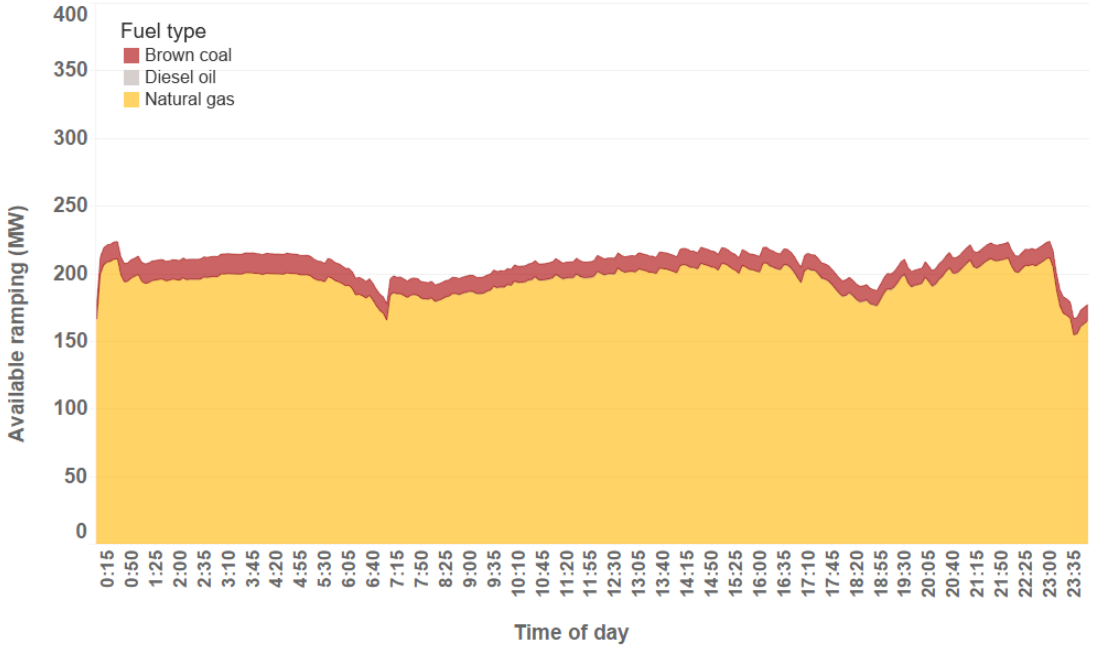


Figure 4.7 Ramping capacity in South Australia in 2016, coloured by fuel type



Upgrades to existing generators

The Commission understands that fast start generators can undertake measures to reduce the synchronisation time and/or increase ramping capability. For example, gas

peaking plant can be configured to bypass some stages of the start-up process before energy is provided to the grid. This can allow units to run at "full speed, no load" and synchronise very quickly (perhaps, 1-2 minutes) when required. The Commission is aware of at least one generator in the NEM that has this functionality. Five minute settlement would provide generators with a greater incentive to undertake upgrades such as this.

Demand response

Another source of fast response in the short run could come through demand response from electricity consumers. Participation in the wholesale market can be in the form of spot price exposure, spot pass-through arrangements, or benefit-sharing arrangements between loads and retailers. A 2016 survey on the current status of demand response in the NEM found that there is upwards of 2,500 MW of demand response active in the market.[102] This is based on estimates of 2,000 MW from large industrial facilities such as aluminium smelters, 235 MW aggregated by retailers,[103] and 300 MW aggregated by specialist demand responses service providers. These figures are static and it is unlikely that this full response would be available at the same time.

The consultants that undertook the survey estimated that, across a demand response portfolio, 10 per cent of the demand response could be provided within five minutes, 70 per cent in half an hour and the remainder within an hour.[104]

Energy storage

The final source of fast response in the short-run is energy storage in the form of batteries. With the exception of pumped-storage hydro, the Commission understands that most energy storage in Australia is for standby power applications, such as telecommunications exchanges, data centres, hospitals and other critical loads.[105] Much of this storage capacity is probably not participating in the wholesale electricity market. There are a number of pilot projects being undertaken with agencies such as the Australian Renewable Energy Agency,[106] and jurisdictional incentive schemes.[107]

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102 Oakley Greenwood, *Current Status of DR in the NEM: Interviews with Electricity Retailers and DR Specialist Service Providers*, prepared for the AEMC, 30 June 2016.

103 Of this 235 MW, only 35 MW responds to a price signal provided by the retailer. The other 200 MW is exposed to the spot price. The 235 MW figure captures the demand response capability of seven retailers in the NEM. It does not include two retailers that declined to provide this data for the survey, but are understood to have a material amounts of price responsive load.

104 *Ibid.*

105 Ecoult, consultation paper submission, p. 1.

106 Examples include the Lakeland project involving a 10.8 MW solar farm and 1.4 MW/5.3 MWh lithium ion battery system, as well as pilot projects run by Ergon Energy, Ausnet Services, SAPN and United Energy/AGL.

107 The ACT Government is subsidising battery storage in around 5,000 homes by 2020, including ~800 in 2016. The Northern Territory Government offers grants of up to $2,000 towards the installation of energy storage under its Northern Territory Home Improvement Scheme.

The existing residential market for energy storage is estimated to involve around 7,250 installations.[108] There are a range of businesses offering products that optimise the operation of household batteries,[109] however the proportion of installed systems that participate in the wholesale market is expected to be quite small. Aside from demand management applications above, distributed storage can participate in the wholesale market through platforms such as those offered by Greensync and Reposit Power that provide a service similar to fast start generators to retailers and support services to network businesses. Across the NEM, the amount of energy storage capacity under control via such software is likely to be in the order of the tens of megawatts.

4.3.2 New investments

In terms of new investment, the Commission had considered the following fast response options:

- new investments in gas or diesel generation
- greater volumes of, and faster response from, demand response providers
- energy storage (i.e. utility scale and behind the meter applications).

New thermal generation

New gas and diesel generators are capable of providing a very fast response, both in terms of time to synchronise and time to ramp up. For example, the GE LM6000 turbine can ramp from rest to full load (50 MW) in 5 minutes, which includes 2.8 minutes to synchronise.[110] Wärtsila engines can respond form rest to full load in 2 minutes, with a 10 MW engine ramping at ~98 kW/s during this process.[111] A similar operational capability is demonstrated by diesel generators already installed in the NEM, such as Port Stanvac, Lonsdale and Angaston.[112] When five minute settlement was implemented in the Southwest Power Pool in the US in 2014, there was a three-fold increase in the capacity factor of internal combustion engines.[113]

New OCGT units could be either heavy frame industrial or aero derivative turbines. The GE LM6000 mentioned above is an example of the latter. The key differences between these types of units are:

- Frame units can generally handle a wider range and quality of fuels.

108 500 in 2015 and 6,750 in 2016. SunWiz, *Battery Installations in 2016 exceeded 6750, SunWiz research finds*, newsletter, 30 January 2017.

109 E.g. Evergen, Redback Technologies, Tesla.

110 Data provided by GE in March 2017.

111 Data provided by Wärtsila in September 2016. This ramp rate is for Wärtsila multi-fuel engines. For further information see: Wärtsila, *Value of Smart Power Generation for Utilities in Australia*, white paper prepared by Wartsila and ROAM Consulting, 2014.

112 All three of these power stations feature Cummins diesel engines.

- Frame units have capital costs that are around 25 to 30 per cent cheaper than aero derivatives.

- Individual frame units have larger capacity ratings than aero derivative units. Frame units have ratings in the 125 to 180 MW range, whereas aero derivatives are typically sized around 60 to 100 MW per unit.[114] Hence, a 300 MW power station could require two frame units, or three or four aero derivatives units, which would influence the per megawatt cost of the power station.

- Frame units incur a maintenance penalty when they start up, whereas aero derivatives typically do not. This penalty is measured in equivalent operating hours. For example, a manufacturer may specify that a unit should be overhauled every 25,000 hours of operation, but starting a frame unit more frequently may reduce this to only 12,500 hours, leading to higher maintenance costs. This generally does not apply for aero derivative units, with outages largely based on accumulated running hours.

- Aero derivative units have higher fuel efficiencies than frame units.

Typical OCGT start times and ramp times are shown in Table 4.1 below.[115]

Table 4.1 OCGT start and ramp times

Technology	Time to synchronise (hrs:mins)	Total time to full load (hrs:mins)
Industrial (frame)	0:02-0:05	0:17-0:35
Aero derivative	0:02-0:05	0:06-0:13

Frame and aero derivative turbines can typically synchronise in the same amount of time, but frame turbines require more time to ramp up to full load. In practice, the speed of the ramp will also depend on the condition of the frame unit before it is started. A unit that is still hot from operating earlier in the day will be able to ramp faster than one that has been idle for several days or a week. New frame units can ramp very quickly above their minimum loading. For example, GE 9HA.02 units can ramp at 88 MW per minute, equivalent to 16 per cent of its 544 MW rated capacity per minute.[116]

113 FERC, *Settlement Intervals and Shortage Pricing in Markets Operated by Regional Transmission Organizations and Independent System Operators*, Docket No. RM15-24-000, 17 September 2015, p. 13.

114 Parsons Brinckerhoff, *Technical Assessment of the Operation of Coal & Gas Fired Plants*, prepared for UK Department of Energy and Climate Change, December 2014, p. 13.

115 *Ibid.*

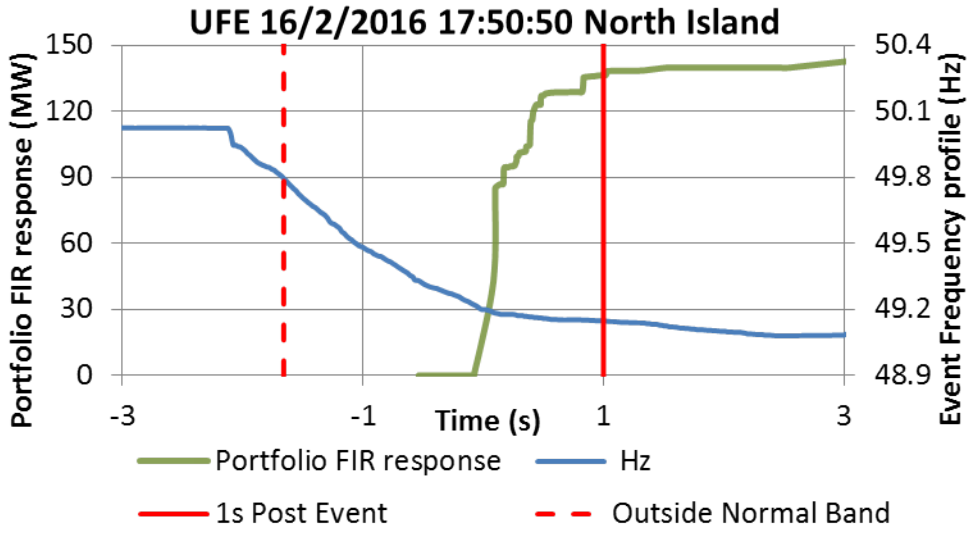
116 GE, *9HA.01/.02 Fact Sheet*, December 2016.

Demand response

As mention in section 4.3.1, it is estimated that 10 per cent of existing demand response capacity in the NEM can be provided within five minutes, compared to 70 per cent within half an hour.[117] This is consistent with feedback that the Commission has received during this project. A key question is whether these responses could be faster if there was a financial incentive to provide this flexibility. Examples of fast demand response internationally are the frequency control markets in New Zealand and Alberta. In May 2016, up to 260 MW of load was offered in New Zealand's North Island market, and 326 MW in Alberta, to provide a response in less than 1 second.[118]

Figure 4.8 below is an example of a ~140 MW demand response provided by EnerNOC customers on New Zealand's North Island on 16 February 2016. EnerNOC's demand response portfolio for the New Zealand frequency control market includes over 130 loads from 12 different industry sectors. The largest contributions come from heavy industry, pulp and paper, and hot water heating.

Figure 4.8 Demand response in New Zealand frequency control market



Source: EnerNOC. FIR = Fast Interruptible Reserves.

The Commission made a rule in November 2016 in relation to the unbundling of ancillary services that will allow new, potentially smaller operators to provide FCAS services. To the extent to which this rule change encourages loads to participate in the FCAS markets, these loads could potentially also provide a demand response in the NEM spot market as well.

117 Oakley Greenwood, *Current Status of DR in the NEM: Interviews with Electricity Retailers and DR Specialist Service Providers*, prepared for the AEMC, 30 June 2016.

118 EnerNOC, *Submission to the Preliminary Report for the Independent Review into the Future Security of the National Electricity Market*, 1 March 2017, pp. 19-20.

The Commission expects that over time technological advances will result in more smaller customers, including commercial and residential customers, providing a demand response to wholesale spot prices. As yet, the Commission is not aware of any retail offerings that involve a spot price pass through to residential customers. However, this service is offered by retailer Flick in New Zealand. Similar business models in the NEM include Mojo Power, which passes through the costs of the wholesale energy contracts that it enters into with generators,[119] and the now defunct Urth Energy, which allowed customers to sell excess solar energy at the wholesale market price.[120] During the February 2016 heatwave in New South Wales, Mojo Power contacted 500 customers offering $25 to reduce their consumption later in the day. The 90th percentile of the responses was a demand reduction of 6 kW, equivalent to approximately 100 per cent of household load.[121] Energy storage is likely to be a key enabler of demand response activities in the commercial and residential sectors of the retail market.

Energy storage

As noted above, non-hydro energy storage currently plays a relatively small part in the wholesale electricity market. In the coming years, a potentially significant increase in energy storage has been forecast, including separate predictions of 1.7 GW by 2024,[122] 6.6 GWh by 2035,[123] and an installation rate of 244 MW per year by 2020.[124]

The economic feasibility of investments in storage is likely to depend on accessing multiple value streams, including:

- avoiding customers' network demand charges
- network support services
- energy ancillary services, and
- participating in the wholesale energy market (i.e. time-shift arbitrage and/or price risk management).

While access to every value stream is not required, the greater the value that can be captured, the more likely it will be for a storage project to be feasible. Further, if storage is deployed to avoid demand charges or for network support applications, it would be a logical step, if circumstances allow, for this storage capacity to also be used in ancillary service and energy markets.

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119 Mojo Power, *Energy today: So just what are wholesale rates?*, blog post, 22 December 2016.

120 Urth Energy, *Urth Trader product flier*.

121 Mojo Power, *Submission to the Preliminary Report for the Independent Review into the Future Security of the National Electricity Market*, 8 March 2017, pp. 6-7.

122 Bloomberg New Energy Finance, *Global Energy Storage Forecast, 2016-24*, 5 October 2016.

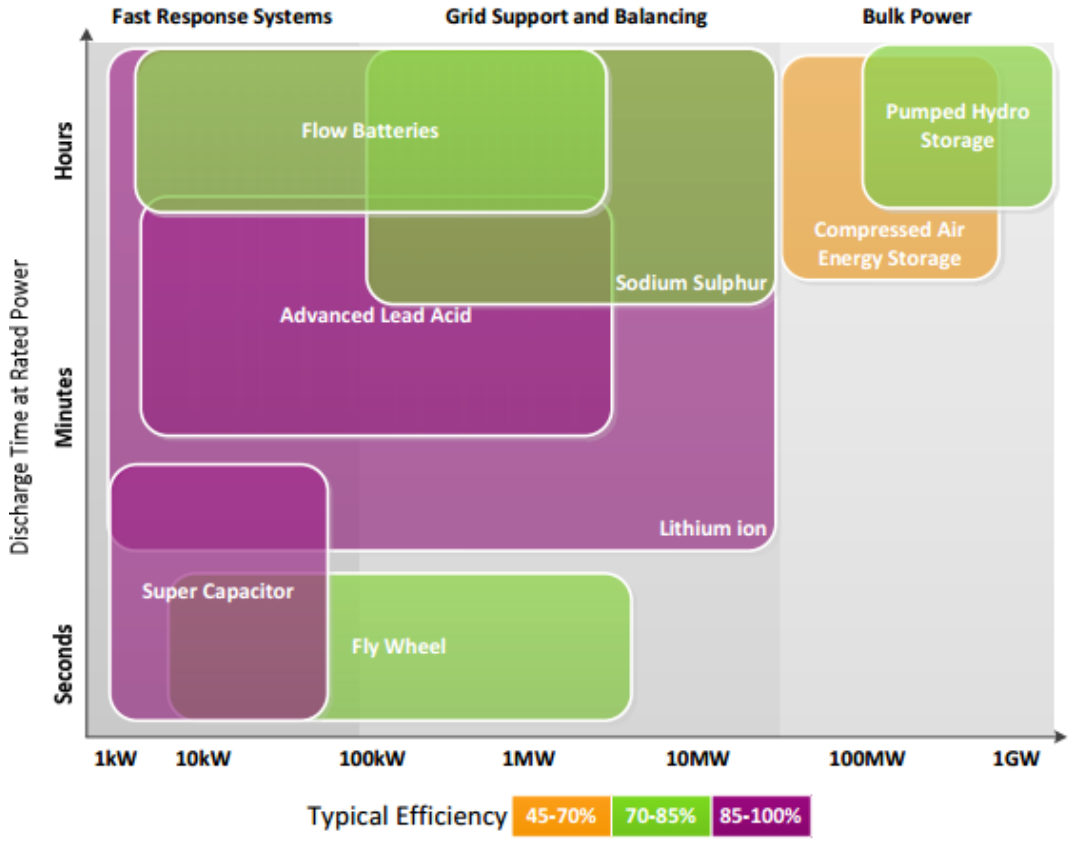
123 AEMO, National Electricity Forecasting Report 2016.

124 Greentech Media, *Can Battery Storage Recharge Australian Utilities?*, 18 July 2016, http://www.greentechmedia.com/articles/read/can-battery-storage-recharge-australian-utilities

A change to five minute settlement could have a direct impact on the incentives of storage operators to participate in the wholesale energy market, and may indirectly impact on the incentives to provide energy ancillary services. Five minute settlement may make it easier for participants to identify the value in providing either an energy or ancillary service, thereby assisting with decision making around which service to offer.

Energy storage comes in a wide range of different forms, with varying capabilities in terms of the amount of energy that can be stored and the length of time for which discharge can be maintained. Figure 4.9 below compares these characteristics for a range of battery technologies.[125] These characteristics, along with technology response times, determine the suitability of the different types of energy storage for particular applications.

Figure 4.9 Discharge time and power capacity of common storage technologies



Source: AECOM.

Internationally, there are examples of a range of battery technologies being used for frequency control applications in power grids where responses within less than one

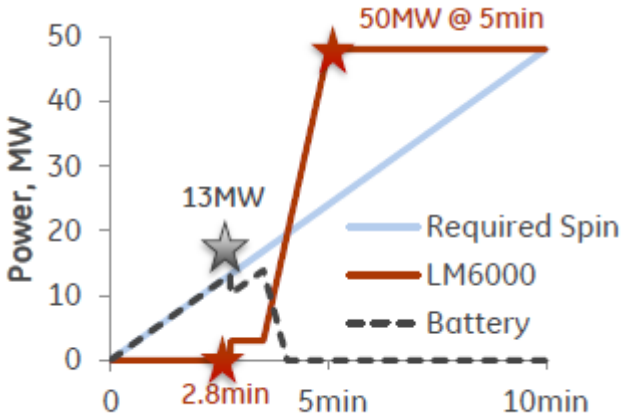
125 AECOM, *Energy Storage Study: Funding and Knowledge Sharing Priorities*, prepared for ARENA, 13 July 2015, p. 27.

second are required.[126] These technologies include lithium ion, flow batteries and advanced lead-acid.[127] Flywheels and super capacitors are other fast response options. All of these technologies have been used in applications where responses within less than one second are required. They may therefore also be suitable for operating in a five minute energy market.

The Commission has identified a range of potential applications for energy storage to provide a fast response within five minutes in the wholesale energy market, including:

- Collocating batteries with existing power stations, such as gas turbines. This arrangement involves discharging the battery system to provide energy in the time that a gas turbine requires to synchronise and/or ramp up. GE offers such a product which integrates a LM6000 turbine (mentioned above) with a 15 MW battery. The combined gas turbine/battery provides a near instantaneous response using the battery, shifting to output from the turbine as it ramps up (Figure 4.10).

Figure 4.10 Operational capability of GE Battery-Gas Turbine hybrid



Source: GE.

- Collocating batteries with wind or solar farms. This arrangement would allow the variable output of a wind or solar farm to be balanced out by the battery (i.e. by either delivering or consuming energy). This would allow these generators to be more responsive to conditions in the market, and potentially capture more value through contracts or on a merchant basis.[128] There may also be power quality and system stability benefits that could be achieved through this

126 GE Energy Consulting, *Technology Capabilities for Fast Frequency Response*, report prepared for AEMO, 9 March 2016.

127 Australian companies involved in the production of non-lithium batteries include 1414 Degrees (molten silicon), Redflow (flow battery) and Ecoult (lead acid/supercapacitor hybrid).

128 Wind and solar off-take arrangements could feature modulating difference payments that expose generators to some price signals from the wholesale market. this is discussed in IEA, *Re-powering markets: Market design and regulation during the transition to low-carbon power systems*, February 2016, pp. 62-67.

configuration. To provide an example, a 13 MW solar farm, coupled with a 13 MW/52 MWh battery, was recently commissioned in Hawaii.[129] This allows for solar generation to be shifted to other times of the day or night. A similar arrangement can be achieved through a wind or solar farm contracting with a battery operator at a different location.

- Standalone utility-scale batteries. MW-scale batteries can be operated in isolation to capture the different value streams listed above, including contracting through the sale of caps to retailers, generators or large energy users. There are currently very few MW-scale energy storage projects in Australia, however the Commission notes that there is considerable interest in this technology. Both the South Australian and Victorian Governments have pledged funding and called for expressions of interest to deploy utility-scale batteries, receiving large numbers of proposals in response.

- Aggregating distributed storage units. Behind-the-meter storage installation can be used in the same way as demand response to reduce energy consumption from the grid. In the commercial and industrial sector, distributed storage can be used to provide a very fast response via the same mechanisms as existing demand response activities (i.e. spot price exposure, spot pass-through arrangements, or benefit-sharing arrangements). In the residential sector there are options involving "virtual power plants" (VPPs), such as the AGL and ARENA project being implemented in South Australia,[130] and businesses that aggregate and control distributed storage to provide services to retailers and network businesses (e.g. Reposit). Products that currently optimise battery operation for households (i.e. to maximise solar self-consumption) could in future be used to access external revenue streams. The proposed SonnenFlat project is an example of this.[131] VPPs and other businesses models that involve the aggregation and control of distributed resources could facilitate significant amounts of fast response in the wholesale market.

The examples above demonstrate the technical potential of energy storage technologies, as well as the potential for upgrades to existing generators, investments in new gas and diesel plant, and demand response technologies. The Commission's research suggests that, over time, technology is providing the ability for faster response technologies and enabling smaller customers to more easily participate directly or indirectly in the wholesale market.

4.4 Analysis: Impact on hedging and risk management

Section 4.3 demonstrated that existing fast start generators are generally not capable of providing large amount of energy if they are responding from rest. However,

129 Utility Dive, *Tesla's dispatchable solar+storage project in Hawaii brought online*, 13 March 2017, http://www.utilitydive.com/news/teslas-dispatchable-solarstorage-project-in-hawaii-brought-online/437858/

130 AGL, *AGL's Virtual Power Plant Goes Live*, media release, 16 March 2017.

131 AFR, *Battery disruptor Sonnen sees market shake-up with 'free' power deal*, 19 February 2017.

hundreds of megawatts of power can be provided from generators that are already running. Participants can also invest in existing technologies that can be highly flexible. The Commission therefore considers that there are ample resources currently in the NEM, and new investments that will occur irrespective of the outcome of this rule change, that can physically respond to five minute prices.

In addition to the criteria that resources can physically respond, in order to make a rule the Commission must be confident that five minute settlement will allow for workable hedging and risk management outcomes. As noted in Chapters 2 and 3, external to the NEM physical market, market participants and intermediaries enter into contractual arrangements to manage the risks associated with volatile wholesale prices. As a result, the prices that retailers offer via retail electricity contracts will depend on their hedging arrangements, including the type, volume and prices of the contracts that they have purchased. The Commission would be concerned if the rule change was to undermine the ability of market participants to manage risk through the wholesale contract market, as this could damage competition in the retail market and lead to higher prices for consumers.

The Commission's consideration of the potential impact of five minute settlement on hedging and risk management is structured as follows:

- Consideration of the different types of contracts.
- Discussion of generator concerns about not being able to defend caps.
- Alternative risk management options (i.e. other sources of caps, and substitutes for caps).

The Commission engaged Energy Edge to provide an assessment of the likely impact of the five minute settlement rule change on the NEM financial markets.[132] The Energy Edge report has been published alongside this paper. The following discussion of the impact of five minute settlement on contracting in the NEM reflects advice provided by Energy Edge, stakeholder submissions and the Commission's analysis.

4.4.1 Types of contracts

The motivation for entering hedging contracts is to convert uncertain future wholesale prices into more certain cash flows that better match upstream and downstream liabilities. For example, retailers are exposed to variable wholesale prices, but offer fixed prices to customers and receive relatively stable income. Retailers typically enter into contracts where the total contracted volume is similar to the electricity volume and profile that they expect their customers to consume. Via contracting, the variable wholesale price can be converted to more stable prices that can be reflected in retail offerings.

132 Energy Edge, *Effect of 5 Minute Settlement on the Financial Market*, March 2017.

The main markets for trading in hedging products are the Australia Stock Exchange (ASX) and bi-lateral trades between parties in the over-the-counter (OTC) market.

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 per cent of trading in electricity derivatives while caps accounted for 16 per cent of the volume.[133] The remaining trading volume consists of different types of derivatives, such as swaptions, floors, collars, and Asian options.

These contracts operate as follows:

- **Swap:** A swap contract trades a given volume of energy during a fixed period for a fixed price (the strike price). The variable wholesale market spot price is, in effect, swapped for the fixed strike price. The contract is settled through payment between the counter-parties based on the difference between the spot price and the strike price. Figure 4.11(a) provides a stylised example of this arrangement. Swap strike prices reflect the sum of expected future spot prices over the relevant contract period and a contract premium. Swaps can be tailored to only apply in specific circumstances (e.g. an option on entering into a swap, or swaption), follow a specified load shape, and have varying levels of firmness.

  The natural seller of a swap is a baseload generator whereas the natural buyer is a retailer. For both parties, the swap is a hedge against spot price volatility. For generators, the swap provides a fixed revenue for the volume of the contract, thereby removing the risk of low average spot prices. For retailers, the swap ensures that a fixed cost will be paid, thereby removing the risk of high average prices. Retailers typically use swaps to hedge the constant, flat component of their customer load profile.

- **Cap:** A cap contract trades a fixed volume of energy for a fixed price when the spot price exceeds a specified price, which is typically $300/MWh. It provides the buyer of the contract with insurance against high prices. The seller of a cap is required to pay to the buyer the difference between the spot price and $300/MWh every time the spot price exceeds $300/MWh during the specified contract period. Figure 4.11(b) provides a stylised example. The arrangement requires the seller of the cap to be generating for most of the period when prices are above $300/MWh, so to earn spot market revenue that can then be paid to the counterparty to the cap. As a result of the one-sided payment obligations arising under a cap, caps are sold in exchange for a positive up-front premium.

  The natural sellers of caps are peaking generators that can generate quickly at times of high spot prices for a relatively short period. Historically, OCGT, hydro and diesel generators have been the biggest suppliers of caps. Through these arrangements, peaking generators receive the premium payment, and derive spot market revenue when they generate, though this revenue is capped at

133 AFMA, *2015 Australian Financial Markets Report.*

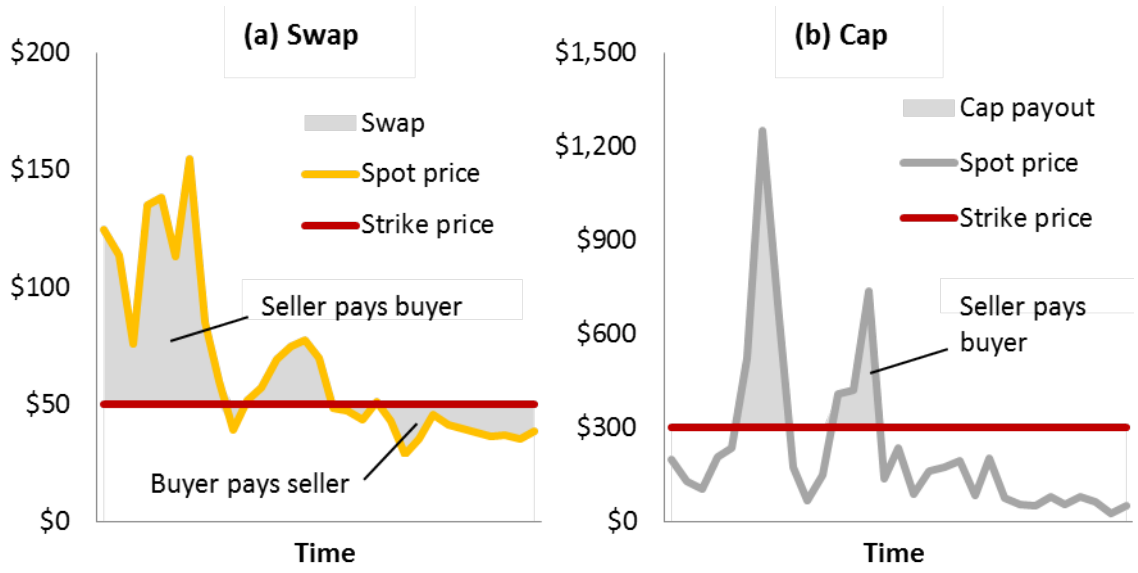
$300/MWh. The natural buyers of caps are retailers and large energy users. Caps are most suitable to hedge load that is variable or less certain.

- **Floor:** The opposite of a cap. The transaction applies if the spot price is less than the strike price. There are usually used as part of a collar (below).

- **Collar:** A cap and floor transacted at the same time. One party buys the cap and sells the floor, while the other party buys the floor and sells the cap. The outcome is that both parties are exposed to spot price movements between the strike price of the cap and the strike price of the floor. However, they are both protected from prices outside of these bounds. The strike prices of the cap and the floor can be chosen so that there is no need for a premium.

- **Asian options:** These are caps or floors where the payoff is based on the average spot price over the period of the contract rather than half hourly spot prices. The length of these products is often one quarter. These contracts are hedges against high or low average prices, as opposed to the half hourly caps discussed above, which provide a hedge against short-term volatility. Because the payout is based on the average price, the probability of a payout is reduced relative to a cap that settled on the basis of 30 minute (or five minute) prices, and premiums will be lower.

Figure 4.11 Example of swap and cap contracts



Of the contract types listed above, it is expected that a change to five minute settlement would impact on the settlement of cap and floor contracts, but not swaps or Asian options. The settlement of swaps and Asian options would not be affected as they typically relate to a fixed volume of energy and/or their duration is always longer than a single half hour. Quarterly and annual products are the most commonly traded. These characteristics mean that the settlement outcome of a firm swap referencing the 30 minute price will be mathematically equivalent to a firm swap referencing five minute prices. Over a period of 30 minutes of more, the average of 30 minute prices will be the same as the average of five minute prices.

Caps are affected because a payout occurs whenever the reference price is above the spike price. If cap contracts are settled against five minute prices, there is the potential for these contracts to pay out more often than a half hourly cap, and therefore have a greater total payout. If a 30 minute price is above a strike price of $300/MWh, then by definition there must have been at least one five minute period within the half hour with a price above $300/MWh. However, the opposite does not hold: if a 30 minute price is below $300/MWh, there may have been five minute periods within that half hour with prices above $300/MWh.[134] This would need to be reflected in the premium paid by the buyer of a five minute cap. A larger payout on the contract would correspond with the buyer paying a higher premium to enter into the contract.

The other factor that would affect the pricing and availability of caps is the ability of traditional sellers to capture high prices. This is not a function of the design of five or 30 minute cap contracts per se, rather it reflects the flexibility of the assets that currently sell these contracts. This is discussed in the following section.

4.4.2 Ability of existing fast start generators to sell caps

A concern raised in relation to fast start generators was that since these assets typically require more than five minute to respond from rest, they would have no certainty of the price they would receive when they are dispatched. This would be compounded by greater exposure to five minute price volatility, in the absence of 30 minute averaging. Stakeholders have suggested that this would adversely impact on the ability of fast start generators to sell and defend cap contracts. A discussion of these concerns is provided below, followed by analysis from Energy Edge on the likely reduction in the volume of cap contracts available for trade.

Loss of "price certainty"

Several generators referred to the scenario involving a price spike early in a half hour. Under the current arrangements, if a price spike occurs at the beginning of a half hour trading interval, participants know that the 30 minute average price will be above a certain threshold. For example, if the prices spikes to $14,000/MWh for five minutes, the 30 minute price will be at least $1,500/MWh, multiple times the short run marginal cost of even the most expensive generators.[135]

In these situations, 30 minute settlement benefits fast start generators as they can commit to generate with the knowledge that they will receive revenues in excess of their fuel and start costs. As noted in Chapter 3, it is also beneficial for generators that require more than five minutes to provide electricity to the market, as they can deliver energy 15 to 20 minutes after a five minute price spike and still receive a relatively high price.

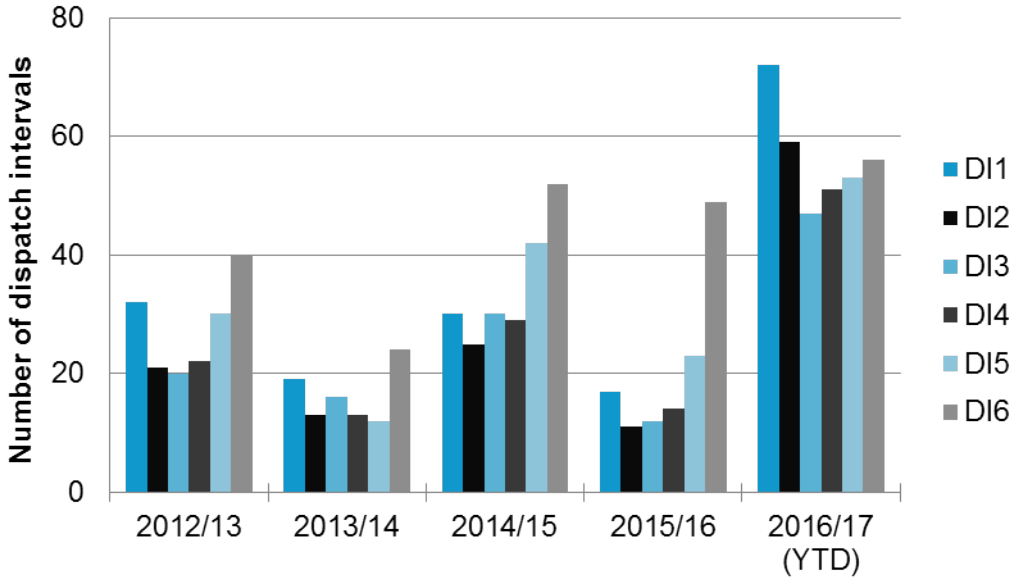
134 Energy Edge, *Effect of 5 Minute Settlement on the Financial Market*, March 2017, pp. 40-42.

135 This outcome arises where there is a $14,000 spike for five minutes followed by 25 minutes at the Market Price Floor of -$1,000. The 30 minute price is calculated as ($14,000 + (5*-$1,000))/6 = $1,500. A recent example of this occurring in South Australia on 21 March 2017 was provided in Chapter 3.

However, the other situation that can arise is a five minute price spike that occurs towards the end of a half hour that very few of the existing fast generators are able to capture. This was identified in the rule change request and several submissions on the consultation paper. The position taken by generators has been to emphasise the benefit of early price spikes, while playing down the risk of late price spikes. This suggests that the benefit to fast start generators of early price spikes offsets the losses incurred from late prices spikes. In the instance of a late price spikes, sellers of caps are required to pay the difference between $300/MWh and the 30 minute price to the buyer of the contract, even though they may have received no spot market revenue for that period.

Figure 4.12 below shows the distribution of dispatch intervals with prices above $2,000/MWh in Queensland and South Australia. It shows that in the last four financial years, it has been more common for >$2,000/MWh price spikes in these two regions to occur in the sixth dispatch interval of a half hour (i.e. DI6). However, in the current financial year, since 1 July 2016, price spikes in the first dispatch interval (i.e. DI1) have been more common. This corresponds with the introduction of the Bidding in Good Faith rule change, which came into effect from 1 July 2016.[136] It may be the case that going forward generators expect early price spikes to be more common than spikes late in the half hour.

Figure 4.12 Distribution of price spikes >$2,000 in Queensland and South Australia



The Commission acknowledges that, under certain circumstances, 30 minute settlement provides a benefit to individual generators. However, it considers that the broader implications of this arrangement are unlikely to provide a net benefit and be in the long term interests of electricity consumers. The examples provided in this section and in Chapter 3 demonstrate that 30 minute settlement rewards generators that provide energy 15 to 20 minutes after a five minute price spikes, when it may no longer

136 AEMC, *National Electricity Amendment (Bidding in Good Faith) Rule 2015 No. 13*, 10 December 2015.

be required. Thirty minute settlement also creates an artificial risk for participants in that they can be caught out by a price spike towards the end of a half hour.

Volatility under five minute settlement

The other concern raised by generators was that five minute settlement would result in market participants being exposed to high levels of price volatility. Some stakeholders were of the view that volatility under five minute settlement would be greater than the volatility under 30 minute settlement. This presumes that the five minute volatility currently observed would be transferred through to five minute settlement. Under five 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 five minute prices.

On the contrary, the Commission's analysis suggests that the existing volatility within the half hour is often a function of the 30 minute averaging. For example, under five minute settlement there would no longer be situations of a $14,000/MWh price spike followed by zero or negative prices when generators all ramp up simultaneously after an early price spikes, at the same time that end users may be curtailing load in response to the same price signal. In the absence of this behaviour, under five minute settlement there should be less five minute price volatility than there is under 30 minute settlement.

Five minute settlement would likely produce 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 five minute volatility under five minute settlement, it is unclear whether volatility would be greater. Regardless, the new volatility would better reflect the physical requirements of the power system, and therefore be a better basis for participants' operational and investment decisions.

Energy Edge analysis

Energy Edge modelled the likely reduction in the volume of caps that fast start generators would be able to sell under five minute settlement.[137] The analysis assumes that fast start generators respond from rest to price spikes that are not anticipated. They are therefore constrained by the time they require to synchronise with the power system and ramp up to full load (as discussed in section 4.3.1). Energy Edge calculated the theoretical reduction in cap volumes for different types of generators based on historical data from 2015 and 2016. The results of this analysis, expressed as a percentage reduction relative to 30 minute settlement, are shown in Table 4.2 below.

137 Energy Edge, *Effect of 5 Minute Settlement on the Financial Market*, March 2017, pp. 50-62.

Table 4.2 Modelled reduction in volume of caps by generator type

Generator type	Reduction in theoretical volume of caps sold
Hydro (conventional)	-18.2%
Hydro (pumped storage)	-46.4%
Liquid fuel	-24.0%
Natural gas (CCGT)	-7.8%
Natural gas (OCGT)	-26.0%
Natural gas (steam)	-29.1%

Source: Energy Edge.

As a further step, Energy Edge calculated the likely reduction in cap volumes on a regional basis, expressed in megawatts of cap contracts. The result is show in Table 4.3. This is an estimate of the reduction in the volume of caps that would otherwise have been traded via the ASX and OTC markets. It does not capture the reduced effectiveness of peaking generators that are used as part of vertically integrated generation and retail portfolios. Energy Edge estimated that the reduced effectiveness of these vertically integrated assets to capture five minute price spikes would be in the order of 20 to 30 per cent.[138]

Table 4.3 Modelled reduction in volume of ASX and OTC traded caps

Region	Calculated underlying traded volume of caps for FY16 (MW flat equivalent)	Reduction in ability to sell caps under five minute settlement	Reduction in cap volumes under five minute settlement (MW flat equivalent)
Queensland	900	24%	-215
New South Wales	1,000	21%	-210
Victoria	470	24%	-115
South Australia	280	30%	-85
Total NEM	2,650	23%	-625

Source: Energy Edge.

Notwithstanding the inefficiency that 30 minute settlement creates, it does appear that it enables the existing fast start generators to sell more caps that they would be able to under five minute settlement. The existing strategies of turning on after a price spikes

138 Energy Edge, *Effect of 5 Minute Settlement on the Financial Market*, March 2017, p. 61.

has occurred would be less effective for fast start generators, unless price spikes are sustained for multiple five minute periods. The ability of existing peaking generators to sell caps would therefore be diminished if they continue to operate in this manner. This suggests that these generators would need to pursue different operational strategies, or market participants would need to invest in other technologies.

4.4.3 Alternative risk management options

On the basis that existing strategies would be less effective, the Commission has considered some alternative options whereby existing generators might be able to continue selling cap contracts. Alternatively, caps could be sold using other technologies, or participants could implement other risk management options.

Some alternative options are:

1. Existing fast start generators changing the way in which they operate so that they can respond faster.

2. Fast start generators and AEMO investing in more sophisticated forecasting methodologies and relying more on these forecasts when making unit commitment decisions.

3. New financial products could be developed that better match the physical capability of existing fast start generators.

4. Baseload generators selling more caps. However, this would potentially be coupled with a reduction in the volume of swap contracts.

An assessment of some of these options is provided in Energy Edge's report. The Commission considers that these strategies could go some way to compensate for the reduction in cap volumes that would result from a move to five minute settlement. However, the volume and price of the replacement liquidity is uncertain. These strategies alone are unlikely to make up for the likely reduction in the volume of caps sold by existing fast start generators.

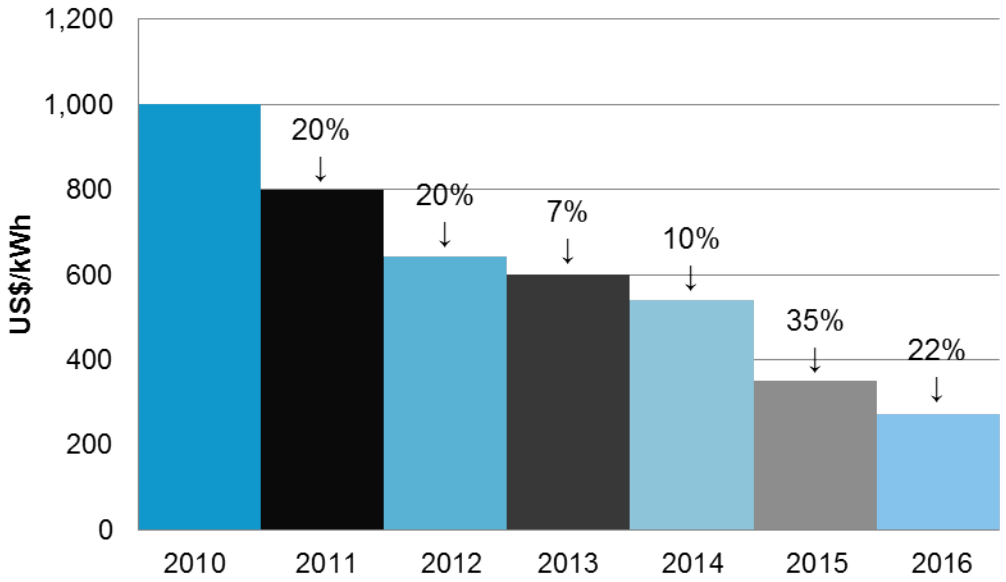
Another source of caps could be from the new investment options identified in section 4.3.2. This section demonstrated that there are energy storage and thermal plant technologies currently available that are highly flexible and could operate effectively under a five minute settlement market design. They may therefore be suitable for selling caps that reference five minute prices.

Batteries can evidently respond very quickly, but do not yet exist at scale in the NEM yet, largely due to their cost relative to other technologies. However, there have been significant advances in energy storage technologies in recent years and material cost reductions, especially in the case of lithium-ion batteries. Figure 4.13 shows cost reductions in the price of the cells and pack.[139] Further reductions are expected as

139 Bloomberg New Energy Finance, *2016 lithium-ion battery price survey*, 14 December 2016, p. 1.

major global production facilities scale up production to cater for demand from electric vehicle manufacturers. Bloomberg New Energy Finance expects the costs of utility-scale lithium ion battery systems (as opposed to just the cells and pack in Figure 4.13) to decline from US$780/kWh in 2016 to US$485/kWh in 2020, a reduction of 38 per cent.[140]

Figure 4.13 Bloomberg New Energy Finance battery pack price survey results, 2010-16.



Source: Bloomberg New Energy Finance. Average prices from surveys of electric vehicle and stationary energy storage industry.

Given the lack of experience with operating utility-scale batteries in the NEM, it is unclear whether battery operators would opt to sell caps. On the basis of stakeholder consultation, the Commission is aware that this option is being actively considered by multiple parties involved in developing utility-scale battery projects. However, other stakeholders that the Commission has engaged with have questioned the viability of this business model.

For the operator of a utility-scale battery, the rationale for selling caps would be similar to existing peaking generators in that it would lock in a fixed income, providing insurance against the potential of low or non-volatile spot prices. However, the characteristics of batteries and their potential to access other revenue streams discussed in section 4.3.2 may detract from the commercial incentive to sell caps. A key difference is that batteries are typically more energy-constrained than OCGT generators. Most utility-scale battery projects under consideration in the NEM involve storage capacities of up to four hours.[141] OCGT generators can usually generate for longer periods than

140 Bloomberg New Energy Finance, *Economic for some: Grid-scale batteries in Australia*, 3 April 2017, p. 8. Includes battery pack (US$330/kWh in 2016), inverter, balance of plant, transformer, energy management system, soft costs, EPC and grid connection costs. Assumes 1 hour of storage.

141 For example, the Victorian Government has called for expressions of interest to build up to 20 MW with up to 80 MWh of battery storage. Lyon Group's announced South Australian Solar Storage

this if they have a gas supply agreement in place and gas withdrawals have been nominated to the pipeline operator the day before. Battery operators may be reluctant to sell caps if windows of high prices are expected to be longer than the energy storage duration of the battery. There may also be some complexity in optimising income across a range of value streams.

Another option involving batteries is the aggregation and control of storage devices located behind the meter. There are already examples of this occurring in the NEM.[142] These arrangements typically involve a retailer, potentially through an intermediary, controlling batteries or providing an incentive to customers so as to reduce the load served by the retailer. If a relatively predictable demand reduction can be achieved in this way, a retailer may be able to achieve a similar risk management outcome to buying a cap contract. This option may not add to the supply of caps, but it would enable retailers to reduce the volume of caps that they need to buy.

New thermal plant, especially diesel generators, could be another source of caps. These technologies are available today and could be deployed relatively quickly.[143] However, the current market dynamics present challenges for investments in these technologies that generally have longer investment horizons than batteries. Among other things, there is uncertainty around the costs of competing technologies, gas availability, carbon emissions policy, the potential for new interconnectors, regulatory change and sovereign risk. Notwithstanding this, there are a few instances where new investments in OCGT generation have been suggested.[144]

Having considered the capability of existing assets, and the costs and deployment times of new investments, the Commission is of the view that if five minute settlement was to be implemented too quickly, existing generators may withdraw from the supply of cap contracts before other options are able to make up the difference. In the interim period, there could be a shortfall in the supply of these contracts. This could result in a range of negative repercussions, such as retailers and large loads being unable to effectively hedge their exposure to spot prices. Unhedged generators may cause prices to be higher and more volatile than if they had been able to enter into contracts. If this was to undermine the viability of non-vertically integrated retailers, including second tier retailers, this would be detrimental for competition in the retail sector.

For these reasons, the Commission considers that if five minute settlement is to be implemented, a transition period is required so that existing assets can be adapted and

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projects feature proposed storage capacities of 4 hours (Riverland) and 2 hours (Kingfisher). Lyon Group, *Lyon Group building $1 billion Riverland Solar and Battery Storage this year*, media release, 30 March 2017.

142 E.g. AGL's VPP, Greensync, Reposit Power.

143 Temporary generators can be deployed in a matter of months. Permanent diesel generators require 12-14 months to be commissioned, while new OCGT investments have lead times of several years.

144 One involves a 350 MW gas power station and floating storage and re-gasification barge (FSRB) in South Australia. The second involves up to 400 MW of OCGT and batteries at the existing Torrens Island power station, also in South Australia. AFR, SA offered new $600m energy answer, 17 March 2017; Advertiser, *Back-up gas plan may zap blackout*, 8 December 2016.

alternative risk management options have time to emerge. The length of a transition period is considered in Chapter 7.

4.5 Analysis: Incentives to invest in flexible technologies

The earlier parts of this paper have observed that a large portion of the existing generation capacity in the NEM is nearing the end of its design life. Large amounts of wind and solar generation is expected to enter the market, resulting in the potential for greater physical variation on the supply-side. All other things being equal, greater physical variation will result in greater price volatility. Spot prices will potentially become highly dependent on prevailing weather patterns, with windy and sunny conditions associated with low spot prices, interspersed by periods of high prices when other technologies ramp up to fill shortfalls in wind and solar output (potentially, by providing surplus energy that was collected earlier). This scenario suggests that there will be a greater need for flexible resources in the near future.

A fundamental question is therefore whether 30 minute settlement provides the best incentives to invest in flexible technologies. To investigate this question, the Commission has considered how changing to five minute settlement may alter the incentives to invest in particular technologies. As context for this discussion, Box 4.1 below provides a comparison of the physical characteristics of OCGT generators and lithium batteries.

Box 4.1 Energy storage and OCGT characteristics

Both OCGT generators and lithium ion batteries have characteristics that make them most suitable for providing energy during periods of peak demand.

Both can respond quickly from rest, but lithium ion batteries can ramp much faster than OCGT generators. As discussed in section 4.3.2 above, even the most advanced OCGT units require several minutes to synchronise with the power system, and several minutes more to ramp up to full capacity. In contrast, the response times of batteries are generally measured in fractions of a second. Batteries can also turn off very quickly, whereas OCGTs require 5-15 minutes to ramp down to allow for deceleration and cooling of the turbine blades. OCGT generators may also be constrained by minimum run times, and the amount of time after a shut down before the unit can be started up again.

Batteries and aero derivative OCGTs have an advantage over heavy frame industrial units in that there is no maintenance penalty associated with starting up. These penalties are in the order of $10,000-$40,000 per unit per start. However, there is some similarity between the OCGT maintenance penalty and the way in which battery manufacturers quote a finite number of cycles (i.e. charges and discharges) that a battery will be capable of in its design life. In the same way that OCGT starts can bring forward the need for the unit to be overhauled, there is an opportunity cost with cycling a battery in that it brings forward the point in time when the battery may need to be replaced.

Batteries are constrained by how long they can charge or discharge for, which will be a function of the initial state of charge of the battery, and the design capacity (MWh) of the battery. Similarly, batteries require some period of time to recharge. Batteries lose some energy as they cycle, resulting in round trip efficiencies in the range of 85 to 90 per cent (i.e. 1.1 MWh of energy must be consumed so as it provide 1 MWh at a later time). This characteristic results in batteries being net energy users. To operate effectively as a net energy user, batteries rely on there being temporal variations in prices which they can arbitrage and/or having access to other revenue streams.

OCGT generators can also be constrained by their fuel source, but generally not to the same extent as batteries.[145] Gas generators typically source gas under gas supply agreements (GSA) with gas producers and gas transportation agreements (GTA) with pipeline operators. These arrangements require generators to nominate their expected gas requirements some period in advance of when the gas will be required. Nomination decisions have to be made 24 hours in advance, after which time there could be material changes in supply and demand conditions. In the absence of GSA and GTA arrangements, a gas generator will be subject to the vagaries of short term trading in gas and pipeline capacity.

These characteristics of OCGT generators and lithium ion batteries go some way to determining the situations in which one technology would be favoured over the other. Generally, a battery is more suitable for discharging during short periods of price volatility, whereas OCGTs are a more economical option in the case of peaks that last for at least several hours. However, batteries will likely become more economical for longer peaks as batteries reduce in cost. Both technologies are also capable of accessing alternative revenue streams which will influence the business case of individual projects.

Chapter 3 demonstrated that 30 minute settlement creates the potential for:

- relatively slow generators requiring 15 to 20 minutes to respond from rest to benefit from a price spike even though the conditions that caused the spike may have already passed, and
- very fast resources that would provide energy for a single five minute period being discouraged from doing so by the fact that it will be paid the average price for the half hour.

In this way, 30 minute settlement benefits technologies capable of providing a response in 15 to 20 minutes while disadvantaging technologies that can provide an instantaneous response. It is not technology neutral. Over time, this will likely result in a generation mix where, relative to five minute settlement, the latter is under-represented and the former is over-represented. Some commentary on how this may manifest in terms of investments in energy storage and gas-fired generation is

145 A possible exception is the Colongra power station, which only has four hours of gas supply before a 24 hour interlude is required so that its lateral pipeline can be refilled.

provided below. Similar considerations apply to demand response technologies, however these are not explicitly addressed here.

Energy storage

A point of contention in stakeholder submissions on the consultation paper was whether 30 minute settlement impedes the entry of energy storage technologies. In discussing this, the Commission notes that there are quite different incentives for investments in behind the meter storage (i.e. residential and commercial) compared to utility-scale projects. Retail customers respond to retail prices whereas a utility-scale battery would be a participant in the wholesale market, responding to wholesale prices.

For retail customers, the rationale to install a battery is generally to maximise the value of energy that is generated from solar PV system. Residential retail prices are typically around 20-30 c/kWh, while retailers may compensate households at a rate of 6 c/kWh for energy that is exported. There is therefore value in using a battery to store energy generated from the PV system, using it to offset consumption at 20-30 c/kWh rather than exported it for 6 c/kWh, or possibly less. Investment in behind the meter storage will therefore largely be a function of retail prices, tariffs structures and the prices that retailers pay for exported energy. As energy storage costs decline, the Commission expects that there will be significant investment in behind the meter storage irrespective of whether five minute settlement is implemented.

The difference that five minute settlement could have on behind the meter energy storage relates to the incentives for these resources to be more actively used in the wholesale market. As mentioned in section 4.3.2 above, behind the meter storage can be aggregated and controlled by retailers and third parties, and operated in a similar was to conventional electricity generation assets. Retail customer could expect to receive some monetary benefit in exchange for their battery being used in this way. There may be less of an incentive for aggregation under 30 minute settlement for reasons that will be explained below. This could result in a few different outcomes, including:

1. Behind the meter storage assets not being aggregated and controlled, leading to a less flexible mix of resources in the wholesale market.

2. Behind the meter storage assets being aggregated and controlled, but being operated in response to 30 minute prices, which would be less efficient than responding to five minute prices.

3. Retail customers not investing in energy storage because, in the absence of wholesale market and FCAS revenue streams, the value proposition of the investment is insufficient.

Utility-scale energy storage investments will be made on the basis of opportunities presented by wholesale prices, and other revenue streams (such as FCAS and network support). Five minute settlement would have more of an impact on these investments than for behind the meter.

Under five minute settlement it would be much more feasible for large batteries to respond to five minute prices. A battery could discharge for a single five minute period to capture a price spike, rather than having to discharge for a whole half hour in order to capture a five minute price spike. Essentially, this means that under five minute settlement it would be possible to capture more revenue with the same sized battery, or the same amount of revenue with a smaller battery (potentially, up to one-sixth the size). It is therefore likely that there would be more investment in utility-scale storage under five minute settlement than there would be under 30 minute settlement.

However, the volatility that is currently observed in five minute prices would almost certainly no longer exist. This implies the benefit to large batteries would not be as significant as analysis of historical pricing data (without accounting for changes in participant behaviour) would suggest. The net effect of the changed volatility in conjunction with batteries being able to capture more revenue per unit of storage is difficult to pre-empt.

Compared to 30 minute settlement, five minute settlement would likely result in more investment in utility-scale energy storage, more participation of behind the meter energy storage in the wholesale market via aggregation, and a marginal increase in the total volume of behind the meter storage in the NEM via a potentially improved value proposition.

Gas-fired generation

In terms of gas-fired generation, five minute settlement would incentive greater flexibility in the choice of units and configuration. For a new OCGT investment, there would be a strong incentive to deploy aero derivative turbines rather than frame industrial units. In the NEM there has been a clear preference for less flexible frame units, which may reflect their lower capital cost compared to aero derivative units and historically low gas prices through to the end of 2010. The presence of 30 minute settlement may have also reduced the financial incentive for investing in more flexible aero derivative OCGTs.

For investments in CCGT plant, a potential flexibility measure is to allow the gas turbine in run in isolation to the steam turbine, essentially allowing it to run as an OCGT. It is the Commission's understanding that none of the exiting CCGT generators in the NEM have this functionality. In the absence of this feature, the start sequence of the gas turbine is constrained by the requirements of the steam turbine (e.g. the plant may be held at set points while steam conditions are managed). A CCGT with bypass would provide the option to operate either as a less flexible but more thermally efficient CCGT, or provide a faster response in OCGT mode, depending on expected wholesale price movements.

The other impact that five minute settlement would have is to change the relative value of gas-fired generation versus energy storage technologies, by more accurately valuing flexible responses. Box 4.1 above discussed the characteristics of OCGT and lithium ion energy storage that would impact on the ability of these technology to capture value in

the wholesale market. Five minute settlement may result in less OCGT generation being built, as it may be more economic to use a different, more flexible technologies.

4.6 Commission's initial position

This chapter has observed that existing fast start generators are generally not capable of providing large amount of energy if they are responding from rest. However, hundreds of megawatts of power can be provided within five minutes from existing generators that are already running.

The examples in section 4.3.2 demonstrate the technical potential of a range of flexible technologies, including energy storage, upgrades to existing generators, investments in new gas and diesel generation, and demand response technologies. The Commission's research suggests that, over time, technology is providing the ability for faster response technologies and enabling smaller customers to participate directly or indirectly in the wholesale market.

The Commission considers that there are ample resources currently in the NEM, and new investments that will occur irrespective of the outcome of this rule change, that can physically respond to five minute prices.

In order to make a rule the Commission must also be confident that five minute settlement will allow for workable hedging and risk management outcomes. The Commission considers that are a range of alternative options could go some way to meeting the reduction in cap contract volumes that would likely result from a move to five minute settlement. However, the volume and price of the replacement liquidity is uncertain. Therefore, the Commission is of the view that if five minute settlement was to be implemented too quickly, existing generators may withdraw from the supply of caps before other options are able to make up the difference. If five minute settlement is to be implemented, a transition period is required so that existing assets can be adapted and alternative risk management options have time to emerge.

The Commission expects that five minute settlement would lead to marginal changes in investment decisions. It would change the relative value of different technologies, such as gas and diesel-fired generation, energy storage, and demand response, by more accurately valuing flexible responses. A range of examples were provided in section 4.5 above. Five minute settlement would provide a greater incentive for:

- More flexible unit choice and configurations of gas-fired generation.
- More automation of demand response activities, so that a faster response can be provided.
- Investment in battery storage technologies, especially utility-scale storage.
- Aggregation and control of behind the meter energy storage resources.

The purpose of implementing five minute settlement would not be to favour or disadvantage any particularly technology. Rather, it would be to produce a more

efficient price signal that more accurately reflects the value of flexible responses. Thirty minute settlement favours slower, less flexible technologies at the expense of more flexible alternatives. Over time, 30 minute settlement will likely result in a less efficient generation mix where customers ultimately pay more for electricity than under five minute settlement. To the extent to which there is a difference in the generation mix and a resulting lower cost under five minute settlement, this would represent the dynamic efficiency gain from making the rule.

5 Design issue: Optionality

In Chapter 3.3.1 of this paper, the Commission indicated its in principle support for aligning the NEM dispatch and settlement intervals, subject to stakeholder feedback on the likely costs and benefits of this change. The Commission has acknowledged in earlier publications that the likely costs and benefits of the rule change will depend on the design of five minute settlement. This chapter discusses the key design issue of "optionality", which refers to whether five minute settlement should be compulsory or optional for certain categories of market participant.

5.1 Sun Metals' view

Sun Metals proposed compulsory five minute settlement for all market generators, scheduled loads and MNSPs (i.e. merchant interconnectors). Registered market customers (i.e. retailers and large energy users) would have the option of being settled on a five minute or 30 minute basis.[146] Retailers would not be required to offer five minute settlement to their customers. Sun Metals' justification for providing this option for Market Customers was that not all loads:

- are capable or willing to undertake rapid demand response
- have suitable metering or SCADA systems to enable participation in five minute settlement.

Sun Metals suggested that optional demand side participation would help to reduce the implementation costs.

Optional five minute settlement for market customers would require AEMO to operate five and 30 minute settlement for different participants. This arrangement would create regional imbalances (i.e. settlement residues) between the money earned by supply-side participants settled on a five minute basis and the money paid by demand-side participants, who could be settled on either a five or 30 minute basis.

Sun Metals proposed a new mechanism to manage the imbalance. The imbalance amount, which could be positive or negative, would be recovered entirely from those demand-side participants who continue to be settled on a 30 minute basis.[147] An alternative option suggested by Sun Metals to manage the imbalance would be to combine the new imbalances with existing intra-regional settlement residues. This alternative treatment would minimise the changes that retailers would need to make to their IT systems in order to manage the imbalance.[148]

146 Sun Metals rule change request, p. 4.

147 *Ibid,* p. 4.

148 *Ibid*, p. 8.

5.2 Stakeholder views

There was only limited support for optional demand-side participation in five minute settlement. Major Energy Users submitted that five minute settlement must not be compulsory for end users. It was also of the view that large users that opt in should also be allowed to opt out if they find the process too limiting.[149] Genex Power indicated that it supported five minute settlement for generators only.[150]

Most other stakeholders that commented on this aspect of the proposed rule were of the view that demand side participants should be settled on a five minute basis. Generators and retailers opposed demand-side optionality on the basis that obligations should be the same for supply and demand-side participants.[151] EnergyAustralia indicated a strong preference for consistent settlement if the rule change is to be implemented. It considered demand-side optionality to be "the most problematic element of Sun Metals' proposal".[152] UnitingCare Australia also expressed its support for five minute settlement applying to all market participants. It submitted that this would reduce the potential for gaming and enhance system transparency.[153]

UnitingCare Australia suggested that if five minute settlements were adopted there should be a transition period after which point all parties are subject to the same rules.[154] Stanwell was of a similar view, suggesting that, if optionality is adopted, there should be a sunset date for 30 minute participation.[155]

The main issues cited by those opposed to optionality were:

- complexity and administrative burden
- the settlement residue
- contract market liquidity and risk management issues.

Complexity and administrative burden

AGL suggested that optionality would increase the administrative burden on both AEMO and market participants, which would have flow on effects for consumer pricing. Stanwell noted that AEMO would have to pre-process and alter information for some participants prior to settlement, and manage multiple settlement solutions.[156] Other participants provided examples of the potential complexity and loss of efficiency

149 Major Energy Users, consultation paper submission, p. 6.

150 Genex Power, consultation paper submissions, p. 1.

151 Consultation paper submissions: Australian Energy Council, p. 1; Engie, p. 6; ERM Power, p. 2.

152 EnergyAustralia, consultation paper submissions, p. 5.

153 UnitingCare Australia, consultation paper submission, p. 10.

154 *Ibid,* p. 10.

155 Stanwell, consultation paper submission, p. 8.

156 Stanwell, consultation paper submission, p. 6.

that allowing demand-side optionality would introduce.[157] EnergyAustralia and Snowy Hydro considered that it would be more complicated to understand, manage and price risk exposure.[158] Origin Energy cited complexity from having to distinguish between five and 30 minute settled customers for billing and settlement purposes.[159] The AEC considered there to be far reaching complexities associated with optionality, such as changes to the Net System Load Profile (NSLP) calculation and complexity in administering the Retailer of Last Resort provisions.[160]

Settlement residue

Another aspect of complexity noted by stakeholders was the settlement residue. As noted above, this residue would be created if some or all demand-side participants continued to be settled on a 30 minute basis. If this is the case the amount of money collected from consumers may not be equal to the amount payable to generators. Most generators and retailers had reservations about this arrangement. They indicated it would increase complexity and risk for generators, increasing costs, and creating opportunities for gaming or unforeseen wealth transfers.[161] Pacific Aluminium was concerned that some of the settlement residue may end up transferring costs from fast response demand-side users to other users.[162]

Stakeholder views were mixed on the proposal for the settlement residue to be recovered from end users that continued to be settled on a 30 minute basis. Based on the analysis of historical data, it is expected that settling some or all demand-side participants on a 30 minute basis would result in AEMO being in deficit. This corresponds with a shortfall in money payable to generators. Origin Energy and ERM Power considered that this would introduce inequality, with consumers that are unable or unwilling to respond to five minute prices having to bear the costs.[163] Origin Energy submitted that, "there is no sound rationale for the recovery of settlement residues in this manner".[164] On the contrary, Stanwell and Intelligent Energy Systems indicated support for recovery in this way.[165] Stanwell noted that recovering costs from end users remaining on 30 minute settlement would be consistent with the "cost minimisation' approach to cost recovery. That is, those with the ability to minimise the cost would bear the burden of the residue.[166] The AER considered that recovery of the

157 Consultation paper submissions: Energy Australia, p. 1; Engie p.6; ERM Power, p. 2.

158 Consultation paper submissions: Energy Australia, p. 5; Snowy Hydro, p. 4.

159 Origin Energy, consultation paper submission, p. 4.

160 AEC, consultation paper submission, pp. 2-3.

161 Consultation paper submissions: Australian Energy Council, p. 3; Energy Australia, p. 5; ERM Power; p. 6; Origin Energy, p. 4; Snowy Hydro, p. 4.

162 Pacific Aluminium, consultation paper submission, p. 2.

163 Consultation paper submissions: ERM Power, p. 6; Origin Energy, p. 4.

164 Origin Energy, consultation paper submission, p. 4.

165 Consultation paper submissions: Intelligent Energy Systems, p. 3; Stanwell, p. 8

166 Stanwell, consultation paper submission, p. 8.

residue in this way would encourage participants to opt-in to five minute settlement.[167]

AEMO supported Sun Metals' alternate proposal that the residues be combined with existing intra-regional settlement residues. They noted that the benefit of this approach would be that it could be incorporated into pre-existing settlement frameworks, avoiding the need for more complex treatment, which would reduce the implementation effort for AEMO and participants.[168] Intelligent Energy Systems also considered this to be a logical option.[169] Several generators were of a different view. Stanwell disagreed with this approach on the basis that the groups that the new residues and intra-regional residues should apply to would be similar but not identical.[170] EnergyAustralia and Engie suggested that incorporating the new residues into intra-regional residue may dilute pricing signals.[171]

Contract market liquidity and risk management

The other major concern raised by generators was the effect that optionality would have on the contract markets. Origin Energy, EnergyAustralia and Stanwell explained that the introduction of optionality would create two reference prices - a five minute price and a 30 minute price. This disparity would skew the incentives to enter into different types of contracts. They suggested that on account of the rule change, current financial products would no longer be "fit for purpose" and they would not be able to manage these risks easily.[172] EnergyAustralia and Origin Energy suggested this was also a material problem for vertically integrated businesses, placing businesses at a cost disadvantage and undermining effective competition in the wholesale market.[173] Snowy Hydro suggested that the potential for uplift payments would increase risks and therefore costs to hedge exposures appropriately.[174] ERM Power considered that having customers settled on a different period to generators would not necessarily be a barrier to contracting, but that it would increase the risk associated with transactions and result in higher costs.[175]

The other contract market impact identified by stakeholders was the potential impact of optionality on the liquidity of financial contracts. Hydro Tasmania and the AEC raised concerns that optionality would split the contract market into five minute- and 30 minute-based contracts, which would reduce the liquidity of the contract market

167 AER, consultation paper submission, p. 2.

168 AEMO, consultation paper submission, p. 4.

169 Intelligent Energy Systems, consultation paper submission, p. 4.

170 Stanwell, consultation paper submission, p. 8.

171 Consultation paper submissions: EnergyAustralia, p. 1; Engie, p. 6.

172 Consultation paper submissions: Australian Energy Council, p. 2; EnergyAustralia, p. 6; Origin Energy, p. 4; Stanwell, p. 5.

173 Consultation paper submissions: EnergyAustralia, p. 5; Origin Energy, p. 6.

174 Snowy Hydro, consultation paper submission, p. 4.

175 ERM Power, consultation paper submission, p. 7.

and increase contract prices.[176] Stanwell likened the impact on contract markets to the introduction and removal of the Australian Financial Markets Association (AFMA) carbon pass-through clause. Stanwell submitted that after the clause was introduced the market became split with some periods of high illiquidity.[177]

5.3 Analysis

The Commission's analysis of the optionality question first considers the price signals that participants could face under optional five minute settlement, and the potential efficiency implications of this arrangement. Commentary is then provided on the issues identified by stakeholders. These are:

- contract market liquidity and risk management
- settlement residue
- complexity and administrative burden.

5.3.1 Price signals under optional five minute settlement

As discussed in Chapter 3, reducing the NEM settlement interval to five minutes would provide an improved price signal that better aligns the financial incentives of market participants with the physical operation of the power system. Settlement on the basis of five minute prices would more accurately value the contribution of flexible resources and signals the physical value of when a demand or supply response is needed by the power system. It thereby incentivises more efficient operation, use and investment decisions. The Commission considers that the core issue with demand-side optionality is that demand-side participants who opt to stay on 30 minute settlement would receive a less efficient price signal than those who opted for five minute settlement.

Until recently, there has been limited capacity for consumers to actively participate in the wholesale market. In the absence of any demand-side involvement in the wholesale market, there would be limited value in demand-side participants being settled on a five minute basis. While current participation is for the most part limited to retailers and large energy users with some level of spot price exposure, the Commission expects that over time technology developments will facilitate greater participation by smaller consumers. Some examples of this were provided in Chapter4.

In the NEM, as outlined in Chapter 3, there is an increasing uptake of demand-side technologies, such as solar PV, battery storage, smart thermostats and building energy management systems. This is leading to more active demand-side participation in the wholesale market. Demand-side participants would make more efficient use and investment decisions in relation to these technologies with the more granular price

176 Consultation paper submissions: Australian Energy Council, p. 2; Hydro Tasmania, p. 2.

177 Stanwell, consultation paper submission, p. 5; p. 10.

signal that five minute settlement provides, either directly via exposure to the spot price or indirectly via retailer product offerings. Similar to the incentives on the supply-side, five minute settlement encourages demand-side participants to:

- Use new technologies, especially those with a high degree of flexibility, in a way that contributes to balancing supply and demand.
- Invest in flexible technologies that can quickly respond to the physical requirements of the power system and complement the non-firm output of wind and solar generation.

In this way, the Commission considers that, over the long-term, providing demand-side participants with a greater incentive to respond to the physical requirements of the power system is likely to promote improved allocative and dynamic efficient outcomes, benefit system security, and be in long term interests of consumers.

5.3.2 Contract market liquidity and basis risk

Stakeholders indicated concerns that demand-side optionality would reduce contract market liquidity and introduce "basis risk" into contracts. This refers to a situation where one or both parties to a contract are settled against a reference price that is different to the reference price of the contract. For example, if a generator was settled on a five minute basis and sold a contract referencing the 30 minute price, this may cause the spot market revenue earned by the generator to differ from the amount that they are required to pay out under the contract. Stakeholders also submitted that optionality would create liquidity issues, as the existing volume of contracts would be split between products referencing either five or 30 minute prices.

The Commission acknowledges that basis risk could arise if generators are settled on a five minute basis but their existing contracts continue to reference the 30 minute price. The same situation would result if generators enter into new contract that reference the 30 minute price. Basis risk would also exist internally for vertically integrated businesses that both operate generation assets and serve retail customers. However, this risk would be mitigated for most types of contracts due to the fact that most commonly-traded contracts are for a fixed volume and are averaged over periods that are longer than thirty minutes. This was discussed in section 4.4. The result is that, for swap contracts and some options, the settlement outcomes from 30 minute settlement are mathematically equivalent to five minute settlement. Therefore, demand-side optionality should not create liquidity issues in the case of swap contracts that are for a fixed volume.

As explained in section 4.4, the exception to this is cap contracts (and the less commonly used floor contracts). The Commission would be concerned if optionality in the design of five minute settlement posed a barrier for participants entering into cap contracts. It is likely that five minute settlement would lead to an initial reduction in the supply of cap contracts. This would create a need for existing assets to be operated differently in order to sell caps and demand for similar risk management products

from new entrants. An implementation where five minute settlement applies for all market participants would seemingly be more conducive to this occurring than an implementation with optionality.

5.3.3 Settlement residue

The Commission's consultation paper provided a stylised example to show how, in situations where energy output or consumption varies within a half hour, settlement outcomes for five minute versus 30 minute settlement can be quite different.[178] Over periods longer than a single half hour, as in the example from the consultation paper, the residues (the "30 minute residues") are expected to be relatively minor in comparison to total settlement value. Notwithstanding this, these discrepancies would create a settlement residue if demand-side optionality was implemented, and some portion of the demand-side continues to be settled on a 30 minute basis.

The 30 minute 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 would be in deficit if there is demand-side optionality.[179] Generators that vary their output in response to five minute prices would be expected to earn more than the demand-side pays, if end users continue to be settled on a 30 minute basis and have no incentive to vary consumption in response to five minute prices.

Two options for dealing with the 30 minute residue are discussed below.

Cost recovery of settlement residue: Sun Metals' proposed mechanism

Sun Metals suggested that the new 30 minute residue be recovered entirely from participants that continue to be settled on a 30 minute basis, using a settlements levy or new ancillary service. This proposal is consistent with the "causer pays" principle as the residue would be caused by those that continue to be settled on a 30 minute basis. It would be avoided by moving to five minute settlement. In theory, demand-side participants could opt into five minute settlement, if the option was available to them, or pay for the imbalance created by staying on 30 minute settlement.

However, the administrative costs incurred in developing and maintaining a new settlement residue mechanism may be disproportionate to the benefit of having this mechanism. In Working Paper 2, the Commission calculated indicative 30 minute residues for each NEM region for the past four financial years.[180]The residue amounts, on a financial year basis, were in the order of a few million dollars. The largest residue was $8.6 million in Queensland in 2015/16. This is very small in comparison to the total volume of NEM settlements, which are in the order of $10 billion a year. If the

178 AEMC, *Five Minute Settlement*, consultation paper, pp. 18-19.

179 AEMC, *Five Minute Settlement Working Group: Working Paper No. 2*, 1 December 2016, section 3.1.

180 An important caveat around this analysis is that is does not account for the fact that historical generator behaviour may have been different had they been settled on a five minute basis.

residues were recovered entirely from customers with Type 6 accumulation metering, the additional costs for an average residential customer would be no more than a few dollars per year.[181] This would be a very weak incentive to be settled on a five minute basis. Therefore, it seems likely that the costs of a mechanism to recover the new 30 minute residues in this way would be greater than the associated benefits.

Cost recovery of settlement residues: Sun Metals' alternative approach

To minimise the administrative burden of developing and maintaining a new settlement residue mechanism, Sun Metals' suggested an alternative approach. This involves combining the 30 minute residues with existing *intra*-regional settlement residues. These are existing imbalances in the settlement transactions within each region resulting mostly from differences between loss factors and actual losses on the transmission network. Under this implementation, transmission network service providers (TNSPs), and eventually all consumers, would pay for any shortfall caused, or benefit from any surplus residue, result from five minute settlement optionality.

Historically, the existing *intra*-regional settlement residues have been usually positive (i.e. a surplus in consumers) and larger than the indicative new settlement residues. Table 5.1 below sets out the residues for each NEM region in 2015/16. Working Paper 2 analysed a period of four years to show that the typically positive *intra*-regional settlement residues usually cancel out the typically smaller and negative 30 minute residues.[182] However, if there are changes in the size or direction of the intra-regional settlement residue and the 30 minute residue over time then this may no longer be the case.[183]

Table 5.1 Settlement residues in 2015/16

Region	*Intra*-regional settlement residue (millions $)	"30 minute residue" (millions $)
New South Wales	17.2	3.5
Queensland	48.5	8.6
South Australia	-4.2	3.6
Tasmania	18.9	0.5
Victoria	28.0	2.4

181 There are approximately 3.3 million consumers with Type 6 meters in Queensland. If the $8.6 million indicative residue from 2015/16 is divided between all of these customers, an average customer would be required to contribute $2.60 for the year. In other years and regions this amount is smaller.

182 AEMC, *Five Minute Settlement Working Group: Working Paper No. 2,* 1 December 2016, section 3.1.

183 The residues may change over time due to operational or regulatory changes, or changes in the generation mix.

This analysis suggests that allowing any new settlement residue to merge with the existing *intra*-regional residues may be an acceptable approach because it would be:

- cheaper to implement than a mechanism requiring the identification of customers who are settled on a 30 minute basis
- no more complex to administer than the existing arrangements

The key issues with combining the 30 minute residues with *intra*-regional settlement residues are:

- All consumers would pay for any shortfall caused by five minute settlement optionality (although they would benefit from any surplus residue).
- Incorporating the residual into the existing mechanism would not provide any incentive for consumers that are metered on an accumulation or thirty minute basis to move to five minute metering. However, the incentive provided by a mechanism that does allocate the costs to consumers who create the imbalance is likely to be very weak.

Whilst the residue arising from this proposal appears to be benign under existing conditions, this may not continue to be the case over time. These factors suggest that allowing new 30 minute residues to merge with the intra-regional settlement residues may be acceptable in the short term, but not as an enduring feature of the market design.

5.3.4 Complexity and administrative burden

Stakeholders have suggested that demand-side optionality would create additional complexity and administrative burden from AEMO and retailers having to operate internal processes to accommodate both five minute and 30 minute settlements. However, it was not clear in all submissions what the baseline was for these additional costs and complexities. Stakeholders may have been comparing either:

1. Five minute settlement with demand-side optionality versus the current 30 minute settlement arrangements.
2. Five minute settlement *with* demand-side optional versus five minute settlement *without* demand-side optionality.

In this section, the relevant comparison is the latter. Undoubtedly, a move to five minute settlement would involve non-trivial costs to most market participants that the Commission will weigh up against the likely long-term benefits of making the rule. These costs are outlined in greater detail in Chapter 7.

If demand-side participation is optional, retailers would only incur costs if they choose to offer retail products that reference five minute prices. It would be at the discretion of retailers to make commercial decisions about whether the potential benefits of the new

product offering would justify the costs to modifying internal processes. Most of the largest retailers in the NEM also own generation assets. For these businesses, a desire to align upstream and downstream business functions would presumably be another factor in the decision.

On the other hand, if five minute settlement is compulsory for market customer, then retailers will face additional costs, principally relating to the data that would be required from their customers. Changes to metering infrastructure and IT systems would be required so that five minute data could be available for settlement by AEMO. This is discussed in detail in Chapter 7. Similar considerations apply for large users that are market customers. A benefit to vertically integrated businesses is that having upstream and downstream operations settled on the same basis would avoid some potential complexity.

The costs to AEMO could be similar irrespective of whether five minute settlement is optional for demand-side participants. Depending on the implementation of five minute settlement, even in an optional implementation AEMO may still need to provide a facility in case a large number of customers need to be settled on a five minute basis. Therefore, there may not be much of a cost saving for AEMO in having demand-side optionality versus compulsory participation.

The Commission acknowledges that an implementation with demand-side optionality would be lower cost than compulsory participation for market customers. These costs will be considered in conjunction with the potential benefits of compulsory participation that have been identified in the sections above.

5.4 Commission's initial position

Sun Metals proposed that under five minute settlement market customers would have the option of being settled on either a five minute or 30 minute basis. This approach would:

- Result in market customers that opt to continue being settled on a 30 minute basis incurring lower one-off metering and data implementation costs, but receiving a less efficient price signal than those demand-side participants who opted for a five minute settlement or supply-side participants.
- Create some ongoing complexity and have some negative impacts on certain types of hedging contracts.

The Commission's initial position is that five minute settlement should apply to both the supply-side and demand-side of the market. Aligning dispatch and settlement would result in an improved price signal that better aligns the financial incentives of market participants with the physical operation of the power system. By doing so it, it signals the physical value of when a demand or supply response is needed by the power system. This provides for improved price signals for the efficient operation, use, and investment on both the supply-side and demand-side of the electricity market. These price signals will be increasingly important as technological developments allow

more end users to become involved in the wholesale market via spot exposure and retailer product offerings.

The Commission acknowledges that in the short-term compulsory five minute settlement means that one-off metering and IT system costs would be higher for those demand-side participants who would have otherwise chosen to settle on a 30 minute basis. However, it considers that these costs are likely to be outweighed by the benefits of the improved price signal and avoiding potential basis risk and liquidity issues with certain types of contracts. In particular, it would be more conducive to existing and new entrant assets being able to sell cap contracts than under an implementation with optionality.

In order to reduce costs in the short-term, the Commission recognises that there may be merit in adopting optionality as a temporary measure to enable an orderly transition to five minute settlement. If this approach is taken, it would be appropriate for new settlement residues to be combined with *intra*-regional settlement residues in order to minimise additional system costs

Question 6 Demand-side optionality

(a) How material are the issues identified around demand-side optionality? Are there any material issues or benefits that have not been identified?

(b) If demand-side optionality is adopted as a temporary measure, should the settlement residues be incorporated in existing *intra*-regional residue settlements? If not, how should they be treated?

(c) How might contracting arrangement evolve if demand-side optionality is adopted on a temporary basis?

6 Design issue: Metering

This chapter concerns the data that would be required to implement five minute settlement in the NEM. It features an evaluation of the implementation option proposed in the rule change request and explores an alternative identified by stakeholders and the Commission. The chapter also provides an explanation of the Commission's initial position on a preferred implementation, should the rule be made. While the Commission is yet to make a decision on whether five minute settlement should be implemented, it is providing this information so that stakeholders can assess the likely impacts and costs that would be involved. Stakeholders have indicated this was required in considering how they should respond to the rule change proposal.

6.1 Sun Metals' view

Sun Metals proposed that five minute settlement be implemented by AEMO using operational data from SCADA systems to profile 30 minute energy readings into five minute periods within the respective half hour. Market participants would have the option of installing five minute interval meters at their own cost.[184]

Sun Metals considered it likely that some market participants will prefer the improved reliability of meter data over SCADA profiling.[185]

Sun Metals noted that the SCADA implementation coupled with optional five minute interval metering would involve costs to AEMO, metering data providers (MDPs), generators and retailers.[186]

6.2 Stakeholder views

AEMO explained that it currently uses SCADA data to assess whether the power system is operating within its technical envelope.[187] AEMO submitted that SCADA data itself is not suitable for energy settlement purposes, but coupling it with 30 minute revenue metering could overcome the concerns around its use.[188] This is a view shared by the AER, who stated that the combination of SCADA and 30 minute metering offers a pragmatic, low cost solution for all generators and a significant number of demand-side participants.[189]

The Australian Energy Storage Alliance, UnitingCare Australia and Intelligent Energy Systems were also of the view that SCADA data can be used for five minute

184 Sun Metals rule change request, p. 3.

185 *Ibid*, pp. 9-10.

186 *Ibid*, pp. 9-10.

187 AEMO, consultation paper submission, p. 2.

188 *Ibid*, p. 3.

189 AER, consultation paper submission, p. 1.

settlement.[190] Reposit Power suggested that the SCADA profiling implementation is possible and beneficial for both sides of the market. It also submitted that demand-side participants could be profiled using energy management systems, which would increase the accuracy of the SCADA data.[191]

Generators and retailers raised concerns around the relative inaccuracy of SCADA data,[192] how missing data would be accounted for,[193] inconsistencies in how it is measured,[194] and the complexities of how SCADA data and other data would be combined.[195] Engie noted that SCADA data lacks the appropriate level of accuracy required for dealing with large sums of money.[196]

Some stakeholders were concerned about the role of AEMO in using SCADA data, submitting that modifying meter data prior to its use in settlement would be outside of AEMO's remit as market operator.[197] Stanwell was of the view that for SCADA data to be used for settlement, it would require improvements that may negatively impact on existing uses of SCADA.[198] Stanwell also observed that not all market generators, few market customers and even fewer end users have SCADA data available, which would limit participation without increasing costs.[199]

Some stakeholders commented on an alternative to using SCADA data profiling that would involve the adjustment of existing revenue meters. AEMO noted that most meters installed in the past ten years should be able to be reprogrammed remotely to accommodate five minute settlement, however a long lead time will be required to swap out the large stock of older meters. They suggest that the costs of individual meters may be relatively small, but the labour costs would be significant.[200] Other stakeholders also considered that there would be significant costs from replacing existing metering equipment to implement five minute settlement.[201] The AEC and EnergyAustralia suggested the likely costs of replacing meters casts doubt over the viability of the rule change.[202]

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190 Consultation paper submissions: Australian Energy Storage Alliance, p. 4; Intelligent Energy Systems, p. 2; UnitingCare Australia, p. 9.

191 Reposit Power, consultation paper submission, p. 1.

192 Consultation paper submissions: AGL, p. 3; CS Energy, p. 2; Engie, p. 5; ERM Power, p. 5; Origin Energy, p. 4; Snowy Hydro, p. 3; Stanwell, p. 6.

193 EnergyAustralia, consultation paper submission, p. 4.

194 E.g. Snowy Hydro, consultation paper submission, p. 3.

195 E.g. Hydro Tasmania, consultation paper submission, p. 1.

196 Engie, consultation paper submission, p. 5.

197 Consultation paper submissions: AGL, p. 3; AEC, p. 2; Snowy Hydro, p. 3; ERM Power, p. 5.

198 Stanwell, consultation paper submission, p. 6.

199 *Ibid*, p. 6.

200 AEMO, consultation paper submission, pp. 3-4.

201 Consultation paper submissions: AGL, p. 3; AEC, p. 2; EnergyAustralia, p. 2; ERM Power, p. 6.

202 Consultation paper submissions: AEC, p. 2.; EnergyAustralia, p. 2.

The Australian Energy Storage Alliance was of the view that metering technology has progressed to a point where replacing revenue meters is likely to be cost-effective.[203] It noted that customers who install energy storage systems will be embracing current technologies, therefore the cost of providing metering equipment that supports five minute settlement is not considered to be a significant concern for these customers.

6.3 Analysis

6.3.1 Using SCADA profiling in settlement

Sun Metals' proposed implementation option involves using SCADA data to allocate, or profile, 30 minute energy readings to five minute periods within the respective half hour. The main benefit of this approach is that it could be implemented by AEMO using existing data, thereby limiting transition costs to AEMO and market participants. The main drawback is that SCADA data is not of the same quality as data from revenue meters as it exists for the purposes of operating and managing the security of the power system.

Stakeholders have indicated that an implementation of five minute settlement involving SCADA profiling would need to address:

- concerns about the accuracy and reliability of SCADA data
- differences in the location of SCADA monitoring systems at power stations
- whether the process would be consistent with the National Measurements Act.

The Commission also considers that the SCADA implementation needs to be evaluated in terms of the availability of SCADA data (i.e. the categories of market participants that provide SCADA data to AEMO) and its suitability for demand-side settlement.

Accuracy, reliability and basis of measurement

In its consultation paper, the Commission compared the accuracy and reliability of revenue quality and SCADA data. The accuracy standard for revenue metering at scheduled generating units is between +/-0.5 and +/-1 per cent. This is specified in an Australian Standard. There is no defined accuracy standard for SCADA, though the Commission understands that accuracy is typically between +/-2 and +/-4 per cent. The processes for dealing with missing or erroneous data in the case of revenue metering and SCADA data are set out in separate AEMO Procedures. As is to be expected, the processes relating to revenue meters are more rigorous. They include detailed rules and methodologies for the 30 different ways in which metering data can be substituted or forward estimated for different types of meter installations.[204] For SCADA data, AEMO uses a quality flag system involving validation at the system level (before it is transmitted to AEMO) and within AEMO's systems. Maximum outage

203 Australian Energy Storage Alliance, consultation paper submission, p. 4

204 AEMO, *Metrology Procedure: Part B*, 15 May 2015.

times of between six and 48 hours over any twelve month period are allowed, beyond which corrective action must be taken.[205]

Differences in the location of SCADA monitoring at power stations would necessarily lead to different bases for the measurements determining the SCADA profile. SCADA data can exist for "as-generated" or "sent-out" power. The former is measured at the terminal of each generating unit whereas the latter reflects power at the point that the power station is connected to the network. The difference between the two is the auxiliary load of the power station (e.g. to run coal crushers, pumps and fans).

The Commission considers that while SCADA data would be unacceptable if the absolute power values were used in financial settlement, from an accuracy and reliability perspective it is likely to be adequate for energy profiling of 30 minute energy values. SCADA data is widely used in the central dispatch process for functions which ultimately determine the prices of energy and some ancillary services. A data standard sets out requirements relating to reliability, data errors and substitution, maintenance, testing and system redundancy.[206] If SCADA profiling was to be implemented, AEMO's processes could be augmented without requiring changes to existing SCADA systems. For example, AEMO could replace missing or erroneous SCADA data with a state estimated value,[207] the last valid reading, or the simple average of the 30 minute energy. If a simple average is used, this would be equivalent to the status quo and participants could be no worse off than if they had been settled on a 30 minute basis.

The Commission also notes that in overseas markets where five minute settlement has been implemented, SCADA data is commonly used for profiling revenue quality measurements (e.g. New York, California, South-West Power Pool and New England, all in the United States). When five minute settlement commences in the PJM Interconnection, generators will have the option of providing five or 60 minute data. If 60 minute data is submitted, it will be profiled using telemetry values, or averaged if there are issues with the quality of the telemetry data.[208] The Midcontinent Independent System Operator (MISO) proposes that generators will be able to submit either five, 15 or 60 minute resolution data.[209] These examples support the use of SCADA profiling for generator settlement.

The Commission considers that issues relating to the location of SCADA monitoring equipment are manageable and could be dealt with on a case-by-case basis. The location would only pose a problem for SCADA profiling if auxiliary loads vary materially over a half hour interval, after a generator has synchronised with the network. AEMO has advised that during normal operation, converting between as-generated and sent-out energy is well-understood and could be modelled as either a

205 AEMO, *Five Minute Settlement*, working paper, November 2016, p. 6.

206 AEMO, *Standard for Power System Data Communications*, final determination, 7 April 2005.

207 State estimation is an optimisation method involving the collection of basic power system variables that are then used to calculate other variables.

208 PJM, *Order No. 825 Compliance Filing*, 11 January 2017, p. 123.

209 MISO Business Practice Manual.

static linear function or piece-wise linear function. More sophisticated algorithms could be developed to reflect the behaviour of auxiliary loads during start-up and shut-down, when significant changes in operation are possible for certain generators.

National Measurements Act

The National Measurement Act 1960 (Cth) (the Act) requires instruments used for trade (including utility meters) to be verified by utility meter verifiers appointed under the Act. The accuracy of the meters must be 'traceable' back to the Australian legal unit of measurement. The National Measurement Regulations and AEMO's Metrology Procedures set out the technical specifications that must be met by meters that provide data to AEMO for settlement purposes. SCADA systems are not verified to be used for trade in accordance with the Act, meaning that it would be illegal to use the absolute values of SCADA data for trade, as defined by the Act and its subsidiary legislation.

The Commission is of the view that the SCADA profiling of metering data would not contravene the Act as meters and their 30 minute data would still comply with the Act. SCADA data would not be used in the measurement of energy, rather, it would be used to determine the price that participants are to pay or be paid for the energy measured by verified meters. The volume of energy generated or consumed would still be traceable to an Australian legal unit of measurement.

Availability of SCADA data for generators

Chapter 5 of the NER specifies that scheduled, semi-scheduled and non-scheduled generating units with a nameplate rating of 30MW or more must have remote monitoring equipment (i.e. SCADA). The SCADA profiling implementation could be used for these categories of market participants. However, there are in the order of 104 market generators, with aggregate rated capacity of 1,041MW, that are below the 30MW threshold. The Commission understands that most, and possibly all, of these generators do not have remote monitoring equipment to provide real-time data to AEMO that can be used for profiling. These units would need to either install SCADA systems or make changes to their existing metering so that they can be settled on a five minute basis.

Availability of SCADA data for demand-side participants

A further consideration is whether the SCADA profiling implementation would be suitable as a means for individual demand-side participants to be settled on a five minute basis. AEMO and some storage proponents suggested that the drafting of the SCADA profiling implementation should be sufficiently broad so that data from non-traceable metering devices (i.e. with less than the full functionality specified by Chapter 7 of the NER) could also be submitted to profile 30 minute data. It was noted that granular data (e.g. one minute) is already available in applications such as commercial building Energy Management Systems (EMS) and behind the meter batteries.[210]

210 Consultation paper submissions: Australian Energy Storage Alliance, p. 5; Reposit Power, p. 1.

The Commission has some concerns with this proposal. EMS and battery control systems are similar to SCADA systems in that while they are outside of the accuracy range specified in the NER, they can reliably produce data at a specified interval. The data is based on a methodology that is applied consistently to all intervals. However, there are differences in the ability of AEMO to verify the data that is provided for profiling. SCADA data can be checked against state estimated values, whereas EMS and battery control system data has no other point of reference (other than the corresponding 30 minute reading). Further, the implementation for this proposal seems impractical as AEMO and MDPs would have to cater for both metering and SCADA data flows, which would be more expensive that if only one option was available. For this reason, the Commission considers that it would be more appropriate for demand-side participants to be settled on the basis of data from five minute revenue quality meters.

6.3.2 Capability of existing metering infrastructure to provide five minute data

A revenue metering solution to implement five minute settlement would have the benefit of avoiding any concerns around data accuracy and reliability, and would be a more suitable means of settlement for demand-side participants. However, it would be more expensive than the SCADA implementation as it would involve changes to metering infrastructure and system changes for AEMO, MDPs and participants. As noted above, stakeholders were generally of the view that a metering solution would involve a much larger implementation effort and be more costly in comparison to the SCADA implementation.

The Commission understands that remotely read interval meters[211] that are less than fifteen years old are usually capable of being remotely reconfigured to provide five minute resolution data. Meters without this functionality would need to be manually reconfigured, replaced, or receive an exemption from having to provide five minute data. Remote reconfiguration would be cheaper than manual reconfiguration or replacement as it would not require a site visit and the changes could be implemented in bulk. However, depending on the functionality of existing meters, there may be added performance benefits from replacing some existing meters.

The Commission understands from its discussions with metering manufactures that commercial and industry end users tend to have their metering replaced when they change retailers. This typically occurs every few years, however some portion of the market will have never changed retailers.[212] Meters used at generation units and in network applications tend to be retained for longer periods, especially in the case of network metering. Legacy electro-mechanical meters have an economic life of 25 years, but some currently in use are over 50 years old. Electronic meters have an economic life of 15 years and tend to be replaced at this time as they either fail or have become

211 Type 1, Type 2, Type 3 and Type 4 meters.

212 The Commission's analysis of Market Settlement and Transfer Solution (MSATS) data indicates that in the year ending 30 September 2016, switching was recorded for close to 17,500 large customer NMIs, a churn rate of just over 20 per cent. The 'large' customer classification is based on jurisdictional definitions.

obsolete. Stanwell noted that its larger sites are equipped with meters that can be reconfigured to record five minute resolution data, however meter replacements are likely to be required for its smaller sites.[213]

Introducing five minute settlement would result in six times as much data being produced. A potential constraint for existing interval meters is that they might not have enough memory to comply with clause 7.3.1(a)(10) of the NER. This clause requires remotely read interval meters to locally store 35 days' worth of data, and for manually read Type 5 meters to locally store 200 days' worth of data. Currently, it is unclear how many meters would be affected by this constraint.

The Commission engaged with meter manufacturers to understand the capability of the meters used in the Victorian Government's Advanced Metering Infrastructure (AMI) Program, which accounts for 75 per cent of interval meters in the NEM. The feedback provided indicates that meters used in the AMI Program are technically capable of recording five minute resolution data and have enough memory to store 35 days' worth of data in most configurations as required by the Minimum AMI Functionality Specification. [214] Firmware changes would be required to activate this functionality. If further investigations reveal that a large numbers of meters would have insufficient data storage capacity and require replacement, a potential relaxation of the 35 day requirement may be considered.

Some stakeholders have suggested that if a meter is reconfigured to record five minute data, the historical 30 minute data would be lost. The Commission considers that this can be avoided by recording five minute data on an additional channel to the existing 30 minute data. The recording of 30 and five minute data could continue temporarily or indefinitely, depending on the preferences of MDPs and market participants. If a meter is replaced then there could be a short outage in the data, however there are existing processes for dealing with this detailed in the NER and AEMO's Metrology Procedures.

A revenue metering solution would also require AEMO, MDPs and market participants to make systems changes to accommodate five minute data. The existing metering data file formats have a field for the resolution of the data that accepts intervals of one, five, ten, 15 and 30 minutes. Presently only fifteen and 30 minute data intervals are in common usage.[215] AEMO has indicated that a revenue metering solution would involve changes to the MSATS Metering Data and Metering Data Management systems. While it is yet to quantify the potential costs of the changes, it considers that they would be classified as a major project, which typically cost more than $2 million.[216]

213 Stanwell, consultation paper submission, p. 7.

214 Department of State Development, Business and Innovation, *Advanced Metering Infrastructure - Minimum AMI Functionality Specification*, September 2013, s 3.2(a)(6).

215 AEMO, *Meter Data File Format Specification NEM12 & NEM13*, 14 May 2014, p. 15.

216 AEMO, *Five Minute Settlement*, working paper, November 2016, pp. 7-8.

MDPs provide metering services to market participants, including the provision of meters, collecting metering data, checking and cleaning metering data, and storing metering data. Under a revenue metering solution to five minute settlement, MDPs would be required to process increased volumes of data, including increased volumes of data that would need to be transferred via communications networks. They would face higher data storage costs and may have to change algorithms for checking and cleaning data (e.g. filling gaps).

Market participants may need to adapt settlement and billing systems to accept more granular data from MDPs. Five minute data may be required for settlement reconciliation, though it is less clear if it is necessary for billing purposes since it is unlikely, at least initially, that many customers would be *billed* based on their five minute consumption. Depending on how systems are configured, it may be possible for an MDP to collect both five and 30 minute resolution data, then send the five minute data to AEMO for settlement and the 30 minute data to a retailer for billing. In this way, it may be possible for system changes, particularly for retailers, to be implemented more gradually in order to minimise transition costs.

6.3.3 A potential implementation with five minute revenue metering

During this rule change process, stakeholders have requested that the Commission provide more detail on the potential implementation of five minute settlement so that they can access the impacts and costs. The information in this section is provided for this purpose.

For context, the following table provides an indication of the number of meters in the NEM by meter type and meter class.[217] The energy thresholds refer to the annual energy transfer for each metering type. Type 5 meters are manually read interval meters, whereas Type 6 are accumulation meters (and also manually read). Of the almost 3.5 million Type 5 meters, 2.9 million are Victorian AMI meters. Despite their classification as Type 5, the Victorian AMI meters can be remotely read.

217 This is a count of meter numbers as at 23 March 2017. There are more meters than there are NMIs as some NMIs have multiple meters. For example: larger customers may separately meter loads at a site that are aggregated for settlement at the NMI level; Type 1 and some Type 2 meters are duplicated for accuracy and redundancy purposes; and residential solar PV customers with gross metering may also have two meters.

Table 6.1 Count of meters in the NEM

Meter class	Type 1 >1,000 GWh	Type 2 100-1,000 GWh	Type 3 0.75-100 GWh	Type 4 <750 MWh	Type 5	Type 6
Generation	130	276	148	138	0	0
Load	12	323	15,152	318,673	3,527,257	9,782,357
Network	44	1,139	706	87	0	0

Data source: AEMO.

To implement five minute settlement with revenue metering, AEMO would require five minute resolution data from all market generators (scheduled, semi-scheduled and non-scheduled). Scheduled loads and MNSPs would also be required to provide five minute resolution data. Metering installations would need to be reconfigured or replaced in all of these situations. No changes would be required for non-market generators as the data from these units does not need to be submitted to AEMO for settlement.

For the demand-side loads, settlement occurs at the market customer level. Market customers are:

- retailers, and
- large energy users with single or multiple sites.

The majority of small customers in all jurisdictions aside from Victoria have Type 6 accumulation metering instead of interval metering. These meters are typically only read every three months. AEMO uses the "Net System Load Profile" process so that the energy from accumulation meters and Type 5 meters can still be settled on a 30 minute basis. This process is explained in Box 6.1

Box 6.1 Net System Load Profile

The NEM settlement process involves developing 30 minute resolution profiles which are used to allocate energy from Type 6 accumulation meters (and Type 5 interval meters, which are manually read approximately every three months) to specific 30 minute periods. There is a separate profile for each distribution network region. Accumulation meter readings have to be reduced to 30 minute intervals to accommodate the NEM's settlement by difference methodology.

The profiles, called Net System Load Profiles (NSLPs), are developed by AEMO as follows:

1. Aggregating all 30 minute energy flows from meters at the boundary of a distribution network region.

2. Subtracting from this aggregate all interval metered loads and other loads as agreed in the settlement procedure for each region (e.g. controlled loads and deemed unmetered loads).

In each network region there is a first tier retailer that was either the incumbent retailer prior to the introduction of full retail contestability (FRC) or acquired the incumbent retailer after FRC was introduced. 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.

Each second tier retailer is settled based on the aggregate load of its customers, shaped to the 30 minute NSLP in the case of its Type 6 accumulation metered customers. All remaining energy is assumed to have been served by the first tier retailer to customers contracted to the first tier retailer who are within its first tier network boundary. As the amount allocated to first tier retailers is determined on a net basis, they bear any risks associated with metering or profiling errors.

The existing arrangements for settlement by difference require:

- 30 minute data from transmission network National Metering Identifiers (NMIs) that contribute to the Net System Load Profile[218]
- 30 minute data from all loads with Type 1, Type 2, Type 3, Type 4 and Type 5 metering installations.

Ideally, five minute settlement would be implemented in the same way, with five minute data from all of these metering installations so that AEMO can create five minute resolution NSLPs. A major advantage of this implementation is that it would allow for all existing Type 6 meters to remain untouched as the energy from these meters could be profiled, as is currently the case, using NSLPs.

The Commission acknowledges that this would be a major undertaking for market participants and is therefore considering ways in which this could be implemented at an acceptable cost. Two possible options are:

- Providing a transition period with a defined date by which meters need to be reconfigured or replaced to that they can record five minute data. The amount of time allowed could be tiered based on meter type, starting with the highest volume meters.
- Only requiring five minute data for new meters or when meters are replaced, which would grandfather 30 minute data for existing meters, or a sub-set of existing meters.

The Commission's preference is for an arrangement where both the supply and demand sides of the market are settled on the same basis. Chapter 5 discussed the

218 These NMIs represent 90 per cent of all WHOLESAL NMIs.

issues associated with some groups of customers continuing to be settled on a 30 minute basis, including that there would be new settlement residues. While the potential residues appears to be benign under existing conditions (i.e. where deficits can be absorbed in the much larger, positive *intra*-regional settlement residues), this may not continue to be the case due to changes in the market. Over time, a new settlement residue could pose more of a distortion than it would appear to today. For this reason, the Commission would favour a transition to a point where all interval meters that provide data for settlement are capable of providing five minute resolution data.

The costs of the change will be a function of the proportion of interval meters that are incapable of being remotely reconfigured and the time frame of a transition. One way of managing the costs could be to specify a transition process for metering changes that is consistent with the inspection and testing requirements specified in Schedule 7.3 of the NER. Tables S7.3.2 and S7.3.3 specify the maximum times between tests and inspections, when a site visit to the metering installation would occur. The maximum times for the different categories and configurations of metering installations are:

- Type 1 metering installations: 2.5 years.
- Type 2 metering installations: 1 year (or 2.5 years if check metering installed).
- Type 3 metering installations: between 2 and 5 years depending on annual energy transferred.
- Type 4 metering installations: 5 years.
- Type 5 metering installations: 5 years.

The benefit of aligning the requirement to provide five minute data with these maximum times is that the marginal cost of reconfiguring or replacing meters could be reduced. Meters that can not be remotely reconfigured will require a site visit so that they can be manually reconfigured or replaced. If the timing is aligned with the test and inspection regime, then the work can take place during a site visit would have occurred irrespective of whether the rule change had been made. The cost for an individual metering installation may be limited to the cost of a replacement meter, if this is required. It is the Commission's understanding that is this most likely to be the case for high voltage Type 1, Type 2 and Type 3 metering installations.

The Commission understands that the AER has allowed alternative testing and inspection methodologies for low voltage Type 3 meters, Type 4 and Type 5 meters that result in some meters being visited less frequently that the times listed above. For example, distribution network service providers (DNSPs) can undertake sample testing whereby some metering installations are never tested but are deemed to be compliant based on a statistical methodology. Practices such as these would need to be taken into account in determining an appropriate implementation timetable for metering changes. An exemption from providing five minute resolution data may need to be provided to non-AMI Type 5 meters given that there are over 600,000 of these that are unable to be

remotely reconfigured. They would likely need to be replaced as they are unlikely to have enough local memory to store 200 days' worth of data at a five minute resolution.

The Commission considers that five minute settlement could commence prior to all interval meters being reconfigured or replaced, so long as a minimum proportion of energy flows are available on a five minute basis. For example, it could commence with five minute data from all high voltage Type 1, Type 2 and Type 3 meters that account for the bulk of energy transfers, with lower volume interval meters included some years later. In the interim period, 30 minute data could be profiled using SCADA if it was available, or the simple average could be used.

The cost of reconfiguring or replacing meters will be subject to commercial arrangements between a Metering Coordinator and the party appointing the Metering Coordinator. From 1 December 2017, an amended version of Chapter 7 will come into effect.[219] Under clause 7.2.1 of the new rules, a financially responsible market participant (FRMP) must appoint a Metering Coordinator, except where a large customer has appointed its own Metering Coordinator. In accordance with new clause 7.6.1, the Metering Coordinator performs its obligations under the rules under terms and conditions commercially agreed between the Metering Coordinator and the appointing party.

In the case of the transmission network metering installations that contribute to the NSLP, the FRMP must appoint a Metering Coordinator and only the FRMP or the Local Network Service Provider can be appointed the Metering Coordinator. The financially responsible parties are first tier retailers.

6.4 Commission's initial position

The Commission is of the view that if five minute settlement is to be implemented, a solution involving five minute data from revenue meters would be most appropriate. The SCADA profiling alternative appears feasible in the case of scheduled, semi-scheduled, non-scheduled generators larger than 30 MW, MNSPs and scheduled loads. However, all generators are opposed to this option, suggesting that they would opt to provide five minute revenue-quality data instead.

Non-scheduled generators smaller than 30 MW are not required to have SCADA systems and, therefore, a revenue metering solution would likely be most cost effective for these generators. The cost of metering changes for generators (in the order of a few thousand dollars per installation, if replacement is required) is not seen as prohibitive.

For demand-side participants to be settled on a five minute basis, existing interval meters should be reconfigured or replaced so that five minute data can be provided for settlement. This includes all transmission network metering installations that are used to compile the NSLP and, to the extent possible, all loads with Types 1 to 5 metering.

219 In March 2017, the Victorian Government announced it will not be introducing the Competition in Metering reforms. The Victorian DNSPs will remain responsible for services for all small customers until at least 1 January 2021 and the Victorian metering specification will remain in place.

Based on current information, it appears likely that many existing interval meters can be remotely reconfigured, which would be less costly than outright replacement. In some cases, certain categories of meters, such as non-AMI Type 5, may need to be provided with an exemption from providing five minute data.

The Commission has proposed a transition period for changes to occur which is aligned with the testing and inspection regime defined in the NER.[220] This has the potential to limit the cost of reconfiguration and replacements. It is proposed that five minute settlement could commence before the end of the transition period for all meters, so long as five minute data is available for high volume metering installations.

The Commission acknowledges that moving to a standard of five minute resolution data will require system changes for AEMO, MDPs and market participants. The Commission welcomes stakeholders views on whether the costs of these changes can also be managed via a transition period between the final rule and five minute settlement commencing. This is discussed in more detail in Chapter 7.

6.5 Potential changes to NER

The Commission's initial position of moving from 30 minute to five minute revenue metering to implement five minute settlement will involve amendments being made to Chapter 7 of the NER. There are other NER amendments that are likely to be required if the Commission makes a rule to move to five minute settlement. However, the focus of this chapter is the changes that would need to be made to introduce five minute revenue metering.

On 26 November 2015, the Commission made the Competition in Metering rule in order to open up competition in metering services in the NEM.[221] This rule amended Chapter 7 of the NER. This new Chapter will commence operation on 1 December 2017. Given the timeframe for the five minute settlement rule change process, and the need for a transition period if the rule is made, any changes to the NER to implement five-minute settlement will be made to Chapter 7 as amended by the Competition in Metering rule.[222]

Possible changes to Chapter 7 would include:

- Changes to the provisions setting out the role and responsibility of Metering Coordinators and FRMPs in relation to metering installations and metering data services, to clarify which party is responsible for implementing changes to metering installations.
- New rules setting out the requirements on the FRMP or the Metering Coordinator to reconfigure and/or replace the meters in accordance with a

220 NER, Schedule 7.3.

221 AEMC, *National Electricity Amendment (Expanding competition in metering and related services) Rule 2015 No.12*, 26 November 2015.

222 NER, Schedule 7.3.

timetable that would be set out in the NER, and provisions specifying what will occur if this replacement does not occur in the time required.

- Changes to the provisions setting out the requirements for metering installation components, for example to amend the requirement for all meters to store interval energy data for at least 35 days if the meter is a Type 1-4 meter.
- Changes to any rules relating to the MSATS Metering Data and Metering Data Management systems to reflect any changes made to those systems.
- Changes to oblige market generators (scheduled, semi-scheduled and non-scheduled), scheduled loads and MNSPs to provide five minute resolution data to AEMO for settlement.
- Changes to require metering installations to be reconfigured or replaced.
- Amendments to the Schedules in Chapter 7 are also likely to be required.

In addition to the possible amendments referred to above, transitional provisions are likely to be required in the NER if there is a period of transition during which meters are to be reconfigured or replaced. Relevant definitions in Chapter 10 of the NER will also need to be amended, and changes to AEMO's Metrology Procedures are also likely to be required.

Question 7 Metering issues

The Commission proposes reconfiguring or replacing existing interval meters so that five minute data can be provided for five minute settlement.

(a) Are there any suitable alternatives to collecting five minute data from the transmission network metering installations used to compile the NSLP other than reconfiguring or replacing the existing meters?

(b) What percentage of meters can be remotely reconfigured? What would this process look like and what would costs be? Conversely, what percentage would be need to be manually reconfigured or replaced?

(c) The Commission has proposed aligning the transition with the timeframes for the NER test and inspection regime. Would this provide an appropriate amount of time for changes to occur?

(d) For which categories and situations should an exemption from providing five minute data be considered? Why?

(e) Are there any other metering implementation issues relevant to collecting five minute data that should be considered?

7 Costs and transition

Previous chapters have set out the potential benefits of five minute settlement and provided reasoning for why, if five minute settlement were introduced, it should be mandatory for all wholesale market participants. The alignment of dispatch and settlement results in financial incentives being matched to the physical operation of the market. This provides the benefit of improved price signals for the efficient operation of the wholesale market, the efficient consumption of electricity, and efficient investment in generation and demand-side technologies.

However, as the existing 30 minute settlement framework has been in place for nearly two decades, there are likely to be large costs and practical challenges associated with implementing five minute settlement. Contracts, metering systems and IT systems have all been designed with reference to 30 minute settlement.

For the introduction of five minute settlement to be in the long term interest of consumers, the Commission must expect the benefits of the proposed change to exceed the costs. This chapter assesses the:

- cost and practical issues associated with introducing five minute settlement as it relates to contracting, metering and IT systems
- potential for costs and risks of implementation to be reduced or mitigated through the use of an appropriate transition period.

7.1 Sun Metals' view

Sun Metals estimated that the costs of implementing five minute settlement may be in the order of $10.27 million in present value terms. This included $7.09 million in upfront costs and ongoing annual costs of $560,000.

Sun Metals also did not address transitional issues or a transitional period for the introduction of five minute settlement. Sun Metals did though submit that optional demand-side participation in five minute settlement (section 5.1) and the use of SCADA data (section 6.1) would mitigate implementation costs.

7.2 Stakeholder views

7.2.1 Implementation costs

In the absence of detailed design and implementation approaches for five minute settlement in the consultation paper, stakeholders did not generally provide estimates of the costs that would be incurred in a move to five minute settlement. Several

stakeholders submitted that the high costs were likely to outweigh the uncertain benefits.[223]

Hydro Tasmania submitted that "the high costs of this change will clearly exceed the benefit".[224] The Clean Energy Council noted that moving generators to obligatory five minute dispatch would undoubtedly create costs that are hard to reconcile against theoretical benefits.[225] SACOSS also noted that the proposed change would create substantial costs to the market that would be passed through to consumers and called for a cost-benefit analysis.[226]

The ECA submitted that:

> "...it is much easier to identify the costs than the benefits. The AEMC should seek rigorous cost estimates and interrogate these numbers carefully. ECA would have grave concerns about the AEMC taking at face value cost estimates from businesses who are not interested in market reform."[227]

7.2.2 Contract market issues

Stakeholders emphasised that the rule change would be disruptive and costly for the contract markets.[228] Snowy Hydro noted the importance of the contract markets to manage electricity risk.[229] The AEC submitted that transitional arrangements will be necessary to handle legacy contracts.[230]

Stakeholders highlighted that a move to five minute settlement would likely constitute a market disruption event and provide grounds for termination or renegotiation of those contracts.[231] AGL stated that the introduction of five minute settlement would "elevate prices in the contract market".[232] ERM Power suggested that the increased risks caused by five minute settlement will impact hedging levels and price offers.[233] EnergyAustralia submitted that because the market is central to business to business interactions, an upheaval of these fundamental arrangements risks disrupting liquid

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223 Consultation paper submissions: AEC, p. 1; ERM Power, p. 1; ECA, p. 4; Hydro Tasmania, p. 1; Origin, p. 2; SACOSS p. 1; Snowy Hydro, p. 1; and Stanwell, p. 5.

224 Hydro Tasmania, consultation paper submission, p. 1.

225 CEC consultation paper submission, p. 2.

226 SACOSS consultation paper submission, p. 1.

227 ECA consultation paper submission, p. 4.

228 Consultation paper submissions: AEC, p. 2; Clean Energy Council, p. 2; EnergyAustralia, p. 3; ERM Power, p. 7; Infigen, p. 2; Origin Energy, p. 4; Snowy Hydro pp. 4-5; and Stanwell, pp. 4 & 9.

229 Snowy Hydro, consultation paper submission, pp. 4-5.

230 AEC, consultation paper submission, p. 2.

231 Consultation paper submissions: EnergyAustralia, p. 3; ERM Power, p. 7; Origin Energy, p. 4; Snowy Hydro pp. 4-5; and Stanwell, pp. 4 & 9.

232 AGL consultation paper submission, pp. 2-3.

233 ERM Power consultation paper submission, p. 7.

markets and long-established contract terms. The proposal would create grounds to unwind current contracts.[234]

Stakeholders submitted that major costs would be incurred as a result of renegotiating or terminating existing contracts and in the course of negotiating new contracts to accommodate a move to five minute settlement. The AEC and Origin Energy noted that renegotiation will change the existing bargain between counterparties and therefore create a value transfer.[235] Infigen submitted that redrafting contracts would result in significant administration and legal expenses.[236]

In the absence of detailed design and implementation approaches for five minute settlement in the consultation paper, stakeholders did not provide estimates of the costs or timeframes required to transition the contract markets to five minute settlement.

7.2.3 Metering requirements

Stakeholder views on metering upgrades to accommodate a move to five minute settlement were canvassed in section 6.2. Stakeholder views specifically in relation to a transition involving revenue metering rather than SCADA profiling are set out below.

AEMO noted that most metering installed in the past ten years should be able to be reprogrammed remotely to accommodate five minute settlement, however a long lead time will be required to swap out the large stock of older meters. They suggest that the costs of individual meters may be relatively small, but the labour costs would be significant.[237]

Other stakeholders also considered that there would be significant costs from replacing existing metering equipment for the five minute rule change.[238] The AEC submitted that the likely costs of replacing meters casts doubt over the viability of the rule change. The Australian Energy Storage Alliance was of the view that metering technology has progressed to a point where replacing revenue meters is likely to be cost-effective.[239] It noted that customers who install energy storage systems will be embracing current technologies, therefore the cost of providing metering equipment that supports five minute settlement is not considered to be a significant concern for these customers.

234 EnergyAustralia, consultation paper submission, p. 3.

235 Consultation paper submissions: AEC, p. 2; and Origin Energy, p. 4.

236 Infigen, consultation paper submission, p. 2.

237 AEMO, consultation paper submission, pp. 3-4.

238 Consultation paper submissions: AGL, p. 3; AEC, p. 2; EnergyAustralia, p. 2; ERM Power, p. 6.

239 AESA, consultation paper submission, p. 4

7.2.4 IT system requirements

Stakeholders identified that multiple, complex IT systems would be affected if five minute settlement was adopted.[240] Stanwell noted that "every tool that currently references thirty minute data would need to be investigated, and the majority would likely require alteration to handle five minute data streams".[241] EnergyAustralia submitted that changes to billing systems, data management, energy trading, sales and marketing systems, forecasting and market modelling systems and settlement systems. would be required.[242]

Stakeholders also considered that IT system upgrade costs would be significant.[243] In relation to existing systems, Origin Energy submitted that:

> "the proponents' estimate of upfront costs to generators of $2.78 million, which is based on figures originally reported by NEMMCO, significantly undervalues the actual costs that would be incurred by Origin. This is outside of the ongoing costs associated with additional data processing and analysis, or any costs incurred on the retail side of the business to support the change."[244]

In the absence of detailed design and implementation approaches for five minute settlement in the consultation paper, stakeholders did not provide estimates of the costs or timeframes required to upgrade IT systems.

7.3 Analysis

The analysis in Chapter 3 identified in-principle benefits of five minute settlement. Chapter 4 explored how these benefits might be realised, by assessing the ability of existing and new generators to respond to a five minute settlement framework, and the potential disruption to the cap contract market.

The existing 30 minute settlement regime has been in place for almost two decades. Financial transactions, metering and IT systems are all designed on this basis. The Commission recognises this means that despite the potential benefits identified in Chapter 3, and the capability of existing and new technologies to respond in Chapter 4, there are likely to be significant practical challenges and costs associated with implementation. Some of these costs are likely to be one-off administrative costs, while others may be more enduring costs.

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240 Consultation paper submissions: AEC, p. 2; EnergyAustralia, p. 4; ERM Power, p. 6; HydroTasmania, p. 2; Infigen. p. 2; Orign Energy, p. 3; Snowy Hydro, p. 4; and Stanwell, p. 7.

241 Stanwell, consultation paper submission, p. 7.

242 EnergyAustralia, consultation paper submission, p. 4.

243 Consultation paper submissions: AEC, p. 2; EnergyAustralia, p. 4; ERM Power, p. 6; Infigen. p. 2; Orign Energy, p. 2; Snowy Hydro, p. 4; and Stanwell, p. 7.

244 Origin Energy, consultation paper submission, p. 3.

The Commission has identified the following one-off costs associated with five minute settlement:

- contract disruption and the potential need to renegotiate existing contracts and negotiate new contracts
- metering costs to access five minute data (identified already in Chapter 6)
- IT systems changes.

Of these one-off costs, contract disruption and metering would potentially be inconvenient and create challenges for the timing of any implementation. They are likely though to involve costs of a much lower order of magnitude than those associated with IT system changes. The Commission expects that the changes required to IT systems and processes is likely to affect most market participants, and could be significant.

More enduring costs will arise to the extent five minute settlement creates structural changes to the market. These costs are potentially ongoing. They will result from the effect five minute settlement has on the financial viability of existing OCGTs and the subsequent impact this has on the provision of cap contracts. Given the importance of the contract market, the Commission is concerned about any potential disruption five minutes would have on its liquidity. Detail of the potential disruption to gas peaking generators and the cap contract market was outlined in Chapter 4.

In establishing the expected costs, the Commission considers a key matter is whether any of the identified risks and costs with implementing five minute settlement can be mitigated or reduced through the adoption of a transition process. The potential for transitional arrangements to be used to reduce costs was recognised in exploring the issues of optionality in Chapter 5 and of metering in Chapter 6.

This section examines in further detail the costs and practical challenges of implementation, and the potential for a transitional arrangement to reduce cost in relation to:

- contracts
- metering
- IT systems.

7.3.1 The effects of five minute settlement on the contract markets

The Commission acknowledges the important role contracts play in the electricity market. The contract market reduces price uncertainty for generators and consumers of electricity. It allows generators to manage risk, securing finance and provides signals for ongoing investment in generation capacity. It enables retailers to deliver price stability for consumers, and allows them to secure financing for their own operations.

A move to five minute settlement would disrupt contract market operations, creating two main categories of cost for market participants. These are:

- one-off costs associated with the renegotiation or replacement of existing contracts that endure beyond the implementation date of five minute settlement
- ongoing costs associated with the potential structural change to the market and the expected initial immediate reduction in the supply of cap contracts.

These once-off contract market costs and the potential ongoing costs are discussed in further detail below.

One-off contract negotiation costs

A move to five minute settlement would require the renegotiation of existing contracts, which involve would one-off administration costs. These contracts would need to include provisions to take into account the future implementation of five minute settlement.

One approach to mitigating one-off contract costs of a move to five minute settlement is to adopt a transition period. 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, counterparties may be able to negotiate to:

- change provisions relating to the reference price
- change the strike price to reflect a changed risk profile
- terminate the contract 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
- 'over-the-counter' (OTC) trades
- power purchase agreements (PPAs)
- settlement residue auction (SRA) positions.

Some relevant features of these trading arrangements are summarised in Table 7.1. Each type of contract is considered in greater detail below.

Table 7.1 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	ISDA or contract law	Unlimited	Possible, if included in contract
SRAs	NEL, NER, AEMO Procedures	Up to 3 years ahead	No, but can be terminated

Exchange-traded contracts via the ASX

ASX products can be traded up to 4 years ahead although analysis has shown that most trading occurs within one year of the delivery period.[245]

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 these contracts.

For example, the market operator could create five minute derivatives so that participants could sell out of their existing 30 minute-based contracts and buy the corresponding five minute product. It should be noted that the need to trade out of 30 minute positions would be avoided by having a transition period that is more than 4 years.

Over-the-counter trades

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.[246]

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

245 AEMC, *Five minute settlement working group*, *Working paper No. 2: Design choices, implementation and transition*, 1 December 2016, Sydney.

246 International swaps and derivatives association (2005) *2005 ISDA commodity definition: Sub Annex A* is available at https://www.db.com/company/en/media/Supplement-to-Sub-Annex-A-to-the-2005-ISDA-Commodity-Definitions.pdf

physical market moved to five minute 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.

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.

Power purchase agreements

PPAs are a contract whereby a party agrees to buy a generator's output at a negotiated fixed strike price. Although the electricity generated is still traded through the NEM, a PPA is a financial settlement outside the NEM. It acts in the same way as a swap, whereby the generator receives a fixed price under the contract and the counterparty takes the floating NEM spot price exposure.

Historically, PPA contracts have been bespoke, though they are now widely used in wind and solar applications and follow ISDA convention. Older contracts may be legally quite different to OTC trades and may not have followed ISDA conventions.

It is understood that non-ISDA PPA contracts usually have change of law or regulatory change provisions.[247] However, as each contract is different it is unknown if this is always the case. To the extent that PPAs 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. However, an interpretation of the specific change of law or regulatory change provision in each PPA would be required. There is the need to determine whether a move to five minute settlement triggers renegotiation that is limited to the reference price clauses or a broader renegotiation (or possibly termination) of the contract.

Settlement residue auctions

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

247 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"*.

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. However, moving to five minute settlement may increase the value of SRA units that have already been purchased by causing larger inter-regional residues.[248] This would provide a disincentive to terminate an existing SRA agreement.

Duration of contracts

As discussed, there are limits on the length of forward trading of ASX products and SRA units. There is also a greater level of transparency around these trades than for OTC and PPA trades. Analysis of ASX data shows that for delivery periods in the past five years, the volume of baseload quarterly swaps traded within one year of, or during the delivery period, has been between 60 per cent and 85 per cent of the total volume traded for each product. The result is similar across all four traded regions.[249]

Further analysis suggests that within three years, close to all the open positions in ASX baseload quarterly swaps would have passed the delivery period of these contracts. The AEMC has received anecdotal evidence to suggest that there is a similar trend in the case of OTC trading. AFMA reporting of ASX and OTC trading was that in 2014/15—the most recent reporting year—95 per cent of the volume of swaps, and 97 per cent of cap volume, was for tenors equal to or less than 12 months. While this does not indicate the timing of the delivery period, it does suggest that the bulk of trading activities occurs close to the delivery period.[250]

The analysis above indicates that a significant proportion of contracts are of a shorter duration. However, it is understood that there are some long-dated contracts in the market that have tenors of up to 10 years or more. Participants typically enter such contracts to underpin large capital investments such as in power generation infrastructure and energy-intensive industrial processes.

Summary

This consideration of the different trading arrangements shows that there are avenues potentially available to parties to vary contracts if five minute settlement was introduced. Further, it appears increasingly a significant proportion of contracts are of a shorter duration.

This indicates that, from a contract markets perspective, transitioning to five minute settlement would be a large but not insurmountable undertaking for the NEM and financial market stakeholders. There would though be a one-off cost incurred in renegotiating or terminating existing contracts

248 Consultation paper submissions: AEMO; Liquid Capital.

249 Australian Energy Market Commission, Five minute settlement working group, *Working paper No. 2: Design choices, implementation and transition*, 1 December 2016, Sydney, p32-33.

250 Ibid.

Question 8 One-off contract negotiation costs

(a) To what extent would a transition period mitigate the one-off contract negotiation costs of a move to five minute settlement?

(b) What length of time would be appropriate to enable contracts to either expire or be adapted to take into account the future implementation of five minute settlement?

Effects of a reduction in cap contracts

As discussed in Chapter 4, a move to five minute settlement would potentially result in an initial reduction in the supply of cap contracts. Caps are a risk management product that retailers and large energy users use as protection against high spot prices.

Under existing 30 minute settlement gas peaking generators can offer and physically defend these caps. With five minute settlement, there is uncertainty as to whether these generators will be able to defend and offer the same volume of these contracts. Based on independent advice, it is estimated a move to five minute settlement could decrease the supply of caps by 23 per cent, corresponding to a reduction of 625 MW in the volume of cap contracts that would otherwise have been traded.[251]

A substantial, immediate reduction in the supply of cap contacts is likely to increase wholesale prices and damage retail competition. A reduction in cap contracts being offered would increase barriers to entry for retailers. This will create incentives for market participants to manage risk via vertical integration or horizontal integration, and increase retail market concentration, resulting in higher prices for consumers.

The economics of new types of fast response and flexible technologies is constantly improving. However, as noted in Chapter 4 they do not yet supply electricity on a significant scale. Further, there is uncertainty as to whether they would replace the existing supply of caps that gas peaking generators currently sell.

In assessing the impact on the contract market, it is also not clear how any of the ongoing costs associated with five minute settlement should be quantified. There are already a number of existing issues placing pressures on liquidity in the contract market. It is therefore likely to be difficult to identify and attribute the incremental effect (and cost) that a move from 30 minute to five minute settlement would have on liquidity. For example, existing pressures on liquidity of cap contracts are emerging as result of:

- increasing vertical integration of generation and retail businesses relying on internal natural hedging

251 Energy Edge, *Effect of 5 Minute Settlement on the Financial Market*, March 2017, p. 61.

- lower capacity factors (and certainty of operation) for gas fired plant, as gas price increases feed through and gaining gas supply contract terms and conditions suited to flexible generation operation becomes increasingly difficult.

Given these broader market influences, it is not clear how continuing with 30 minute settlement will improve this situation. In contrast, putting in place arrangements that deliver improved price signals and match payment to the value of the service at that time, promises to give the market an opportunity to respond as efficiently as possible. As noted in Chapter 4, this will potentially result in hedge contracts being supplied by existing generators adopting new operating strategies, or deliver new investment in plant capable and willing to provide hedge contracts.

Based on this assessment, the Commission considers it is likely that with an appropriate transition period, the anticipated reduction in cap contract liquidity could be alleviated. It is the Commission's initial view that the transition period required to manage the renegotiation of any existing terms or new contract terms, would also be sufficient for managing the risk and costs associated with any impact on cap contracts.

Question 9 Effects of a reduction in cap contracts

(a) To what extent would contract market liquidity be affected by a move to five minute settlement, as distinct from other pressures on liquidity?

(b) How would the contract markets adapt to a move to five minute settlement?

(c) To what extent would:

(i) new types of risk management products emerge?

(ii) existing generators develop new operating strategies to underpin hedge contracts?

(iii) new generation plant be able to provide hedge contracts?

7.3.2 Metering requirements

The main reason five minute settlement was not implemented at the start of the NEM in 1998 was due to limitations in metering and data handling technologies. These limitations no longer exist, however existing metering infrastructure and systems are all configured for 30 minute data.

Implementing five minute settlement will involve changes to potentially millions of meters so that they can provide five minute resolution data. In many cases the change can likely be implemented remotely at minimal cost. However, some older meters will need to be replaced and this would incur a moderate one-off cost.

In Chapter 6, the Commission presented the initial position that if five minute settlement is to be implemented, a solution involving revenue metering rather than

SCADA profiling would be most appropriate. This would require all remotely-read interval meters that provide data for settlement to be capable of providing five minute resolution data. Existing Type 6 accumulation meters (used mainly by residential and small business consumers) would remain unchanged as the NSLP data profiling approach could be adapted to five minute settlement. Costs would be incurred in upgrading Type 1-4 meters and remotely-read type 5 meters to be capable of handling five minute data. In Chapter 6, the Commission suggested that an exemption from providing five minute data may be necessary in the case of manually-read Type 5 meters.

The Commission suggested that a transition period consistent with the inspection and testing requirements specified in Schedule 7.3 of the NER may be suitable to reduce the cost of upgrading relevant meters. The NER[252] sets out the maximum times between tests and inspections of the different categories and configurations of metering installations, as follows:

- Type 1 metering installations: 2.5 years.
- Type 2 metering installations: 1 year (or 2.5 years if check metering installed).
- Type 3 metering installations: between 2 and 5 years depending on annual energy transferred.
- Type 4 metering installations: 5 years.
- Type 5 metering installations: 5 years.

If the requirement to provide five minute data is aligned with these maximum times, then the marginal cost of reconfiguring or replacing meters could be reduced.

Under a transition to five minute settlement, market participants would be settled on a 30 minute basis until their meter was upgraded, at which point they would be subject to five minute settlement. As discussed in Chapter 5, a settlement residue would be created to the extent participants continued to be settled on a 30 minute basis. This is because the amount of money collected from consumers may not be equal to the amount payable to generators.

Chapter 6 sets out consultation questions that explore the impacts on metering of implementing five minute settlement.

7.3.3 IT system requirements

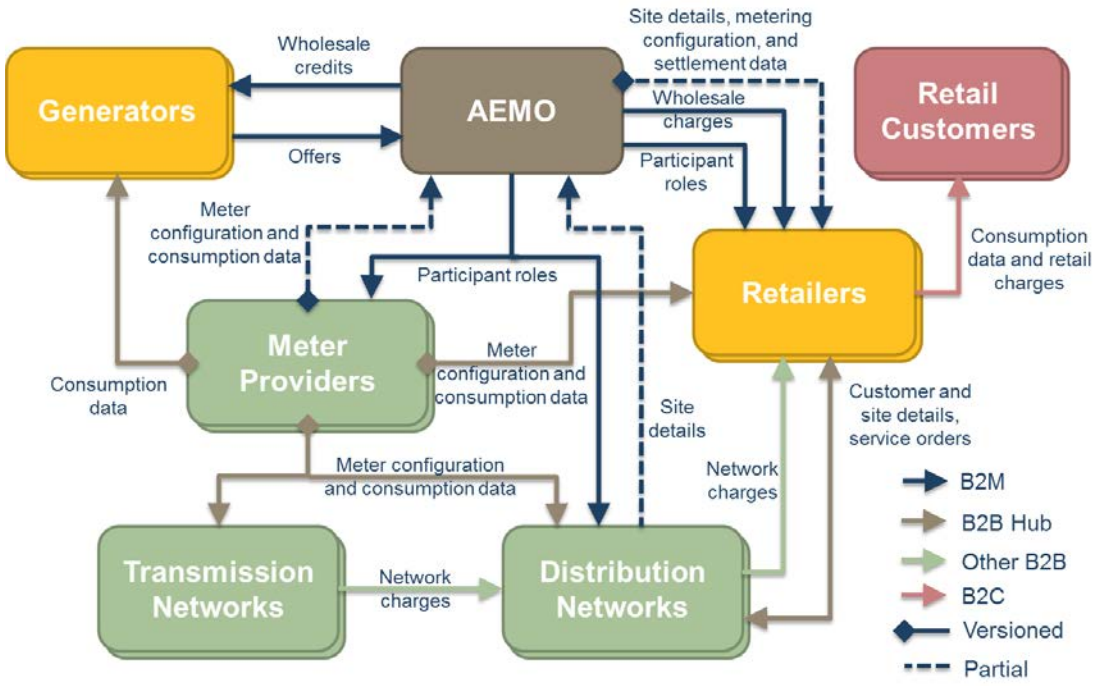
Moving to a standard of five minute resolution data will require information system and process changes for most market participants.

The information flows in the NEM are illustrated in Figure 7.1. It shows that the IT systems of AEMO, MDPs, generators and retailers would be most affected by a move

252 Tables S7.3.2 and S7.3.3

to five minute settlement, as discussed in the second work group paper.[253] The changes mostly relate to system upgrades to handle five minute resolution metering data. For example, changes would be needed to MDP systems for collecting, cleaning and storing metering data, and retailer systems for wholesale market settlement and billing of customers.

Figure 7.1 NEM information flows



Source: AEMO.

IT system upgrade costs are anticipated to be large one-off costs. The Commission has set out its initial views on design and implementation of five minute settlement in this paper. It is seeking feedback from stakeholders on the costs and practicalities of IT system upgrades to accommodate the preferred design and implementation approaches.

While noting the cost of an IT system upgrade is likely to be significant, an appropriate transition timeframe may allow for these costs to be minimised or reduced. This would for example be possible if any changes required from introducing five minute settlement, could be incorporated into a wider IT system upgrade.

253 AEMC, Five Minute Settlement Working Group: *Working Paper No. 2: Design choices, implementation and transition*, Sydney, 1 December 2016 pp. 20-22. See also Australian Energy Market Operator, *Five minute settlement working paper*, November 2016.

Question 10 IT system requirements

(a) What are the costs, synergies and risks involved in upgrading IT systems to accommodate five minute settlement?

(b) What timeframes are required to upgrade IT systems?

7.3.4 Potential transition to five minute settlement

Under the NEL, the AEMC can make a rule that does not 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 five minute settlement.

As noted, implementing five minute settlement would affect contracting arrangements, metering and IT systems. However, as discussed above, there is the potential for both the one-off costs associated with adapting contracts, metering and IT systems, and ongoing costs, to be mitigated or reduced. This can be done through the adoption of a suitable transition period prior to five minute settlement being implemented.

The timeframe related to implementation will influence:

- the level of disruption to the wholesale contract markets with respect to:
  - the extent and one-off cost of contract renegotiation to take into account five minute settlement
  - the expected reduction in the supply of cap contracts and flow-on price effects to consumers
- the size of one-off metering and IT system adaptation costs.

For example, a transitional timeframe would allow for:

- the expiry of most existing contracts and the negotiation of new contracts, which would include provisions to take into account the future implementation of five minute settlement
- existing and new entrant generators to fully or partially address an expected supply shortage of cap contracts
- five minute settlement metering upgrades to coincide with routine scheduled maintenance or replacement therefore avoiding an additional staff mobilisation charge
- the normal IT system development cycle to enable five minute settlement compatible systems to be implemented with little additional cost.

Therefore, one-off or ongoing costs of implementing five minute settlement can likely be mitigated through a suitable transition period. Selecting an optimal transition

period involves identifying a timeframe that is short enough to capture the expected benefits of moving to five minute settlement, while reducing the associated costs and risks.

7.4 Commission's initial position

The Commission is of the view that a transition period can be used to mitigate the one-off and ongoing costs associated with implementing five minute settlement. The Commission is seeking more detailed information on the benefits, costs and risks of the implementing five minute settlement from affected stakeholders. Stakeholder feedback will inform the draft decision.

Selecting an optimal transition period involves identifying a timeframe that is short enough to capture the benefits of moving to five minute settlement while minimising transitional costs and risks. The length of a transition period would be a function of:

- the time for existing and new entrant generators to fully or partially address an expected supply shortage of cap contracts
- the time to transition contractual arrangements
- the time for industry to update systems, processes and metering
- any greater benefit that may be achieved by having five minute settlement sooner.

The analysis above shows that:

- 18 months to 4 years is required for the expiry of most existing contracts that would be affected by five minute settlement, noting that the bulk of ASX and reported OTC trades have delivery periods of less than 24 months. It is acknowledged that there are some long-dated contracts in the market that have tenors of up to 10 years or more. Consideration of the different trading arrangements shows that there are avenues potentially available to parties to negotiate to vary those contracts that endure beyond a transition period.
- Aligning the requirement to provide five minute data with the maximum times between tests and inspections of the different categories and configurations of metering installations (one to five years depending on meter type) would reduce the marginal cost of reconfiguring or replacing interval meters.

Considering these timeframes, the Commission's initial view is that a staged transition period would be appropriate if five minute settlement was introduced, as follows:

1. **Stage A** - a three year period from the time the five minute settlement rule takes effect. During this time:

    (a) NEM participants must have:

(i) upgraded Type 1, Type 2 and Type 3 high voltage meters to be capable of reading and storing five minute data

(ii) implemented IT system upgrades to be capable of handling five minute settlement.

(b) AEMO must have adapted its NSLP process to allow the energy from manually-read Type 5 meters and Type 6 accumulation meters to be settled on a five minute basis.

(c) It is anticipated that:

(i) most legacy contracts will have rolled off and new contracts will accommodate a future implementation of five minute settlement.

(ii) upgrading of Type 4 and remotely-read Type 5 meters to be capable of reading and storing five minute data will be underway.

(iii) AEMO would provide a test environment for five minute settlement.

Five minute settlement would commence at the end of Stage A.

2. **Stage B** - a two year period from the time five minute settlement commences (and Stage A finishes). NEM participants must have upgraded Type 4 and remotely-read Type 5 meters to be capable of reading and storing five minute data any time before the end of Stage B. Type 4 and remotely-read Type 5 meters will be settled on an effective 30 minute basis until their meter is upgraded, at which point they will be subject to five minute settlement.

This approach attempts to balance the benefits of five minute settlement while reducing transitional costs and risks.

The staged approach means that settlement residues (sections 5.3.4 and 5.4) could occur for up to two years as demand-side participants with Type 4 and remotely-read Type 5 meters have the option to switch to five minute data capability during Stage A or by the end of Stage B. The Commission's initial position is that cost recovery of these settlement residues would occur through the existing *intra*-regional settlement residue mechanism. As discussed in section 5.3.4, this is because this mechanism has low implementation costs and weak structural incentives compared with developing a bespoke and temporary settlement residue cost recovery mechanism.

Question 11 Costs and transition

(a) Are there any further categories of costs that would be incurred if five minute settlement was adopted?

(b) How suitable is the proposed two-stage transition period to implement five minute settlement? Do you consider there to be a more preferable approach to a transition period such as alternative timeframes?

(c) What are the detailed benefits, costs and risks of the proposed two-stage transition to five minute settlement on:

(i) existing contract arrangements?

(ii) metering requirements?

(iii) IT system requirements?

(d) Are there any other practical aspects of implementing five minute settlement that should be considered?

A Questions for stakeholders

This appendix sets out the issues the AEMC would like feedback and additional information on for it's assessment of the proposal to move to five minute settlements.

Table A.1 Questions from stakeholders

Question number	Question
1	(a) How suitable is the proposed assessment framework for this rule change request? (b) Are there any additional factors that should be considered in assessing this rule change request?
2	(a) How material are the price signal inefficiencies under 30 minute settlement and are there other data or data sources that would enable this issue to be more comprehensively addressed? (b) What extent would a move to five minute settlement address inefficiency in price signals from 30 minute settlements? (c) Are there any other inefficiencies that should be considered?
3	How does an aging generation fleet together with rapidly evolving digital technologies and the increasing role of intermittent generation affect the prospects of five minute settlement as compared with 30 minute settlement?
4	What kinds of generator bidding behaviours would emerge under five minute settlement as compared with 30 minute settlement?
5	(a) What other issues are likely to be material in considering the introduction of five minute settlement? (b) Is there other data or data sources that can better inform the analysis of the materiality of the problem with 30 minute settlement or the move to five minute settlement?
6	(a) How material are the issues identified around demand-side optionality? Are there any material issues or benefits that have not been

Question number	Question
	identified? (b) If demand-side optionality is adopted as a temporary measure, should the settlement residue be incorporated in intra-regional residue settlements? If not, how should it be treated? (c) How might the contract market react if demand-side optionality is adopted on a temporary basis?8
7	(a) Are there any suitable alternatives to collecting five minute data from the transmission network metering installations used to compile the NSLP other than reconfiguring or replacing the existing meters? (b) What percentage of meters can be remotely reconfigured? What would this process look like and what would costs be? Conversely, what percentage would be need to be manually reconfigured or replaced? (c) The Commission has proposed aligning the transition with the timeframes for the NER test and inspection regime. Would this provide an appropriate amount of time for changes to occur? (d) For which categories and situations should an exemption from providing five minute data be considered? Why? (e) Are there any other metering implementation issues relevant to collecting five minute data that should be considered?
8	(a) To what extent would a transition period mitigate the one-off contract negotiation costs of a move to five minute settlement? (b) What length of time would be appropriate to enable contracts to either expire or be adapted to take into account the future implementation of five minute settlement?
9	(a) To what extent would contract market liquidity be affected by a move to five minute settlement, as distinct from other pressures on liquidity? (b) How would the contract markets adapt to a move to five minute settlement? (c) To what extent would new types of hedge cover emerge? (d) To what extent would existing generators develop new operating strategies to underpin hedge contracts?

Question number	Question
	(e) To what extent would new generation plant be able to provide hedge contracts?
10	(a) What are the costs, synergies and risks involved in upgrading IT systems to accommodate five minute settlement? (b) What timeframes are required to upgrade IT systems?
11	(a) Are there any further categories of costs that would be incurred if five minute settlement was adopted? (b) How suitable is the proposed two-stage transition period to implement five minute settlement? Do you consider there to be a more preferable approach to a transition period such as alternative timeframes? (c) What are the detailed benefits, costs and risks of the proposed two-stage transition to five minute settlement on: (i) existing contract arrangements? (ii) metering requirements? (iii) IT system requirements? (d) Are there any other practical aspects of implementing five minute settlement that should be considered?

Abbreviations

AEMC or Commission	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AESA	Australian Energy Storage Alliance
AFMA	Australian Financial Markets Association
AMI	Advanced Metering Infrastructure
ASX	Australia Stock Exchange
CCGT	combined-cycle gas turbine
DNSP	distribution network service provider
EMS	Energy Management System
FCAS	frequency control ancillary services
FERC	Federal Energy Regulatory Commission
FRMP	financially responsible market participant
ISDA	International Swaps and Derivatives Association
MDP	metering data provider
MISO	Midcontinent Independent System Operator
MNSP	market network service provider
MSATS	Market Settlement and Transfer Solution
NEL	National Electricity Law
NEM	national electricity market
NEO	national electricity objective
NER	National Electricity Rules
NMI	National Metering Identifier
OCGT	open cycle gas turbines

OTC	over-the-counter
SCADA	supervisory control and data acquisition
TNSP	transmission network service providers
VPP	virtual power plant