SCHEDULING AND AHEAD MARKETS

This paper includes:

1. Context, including notes on use cases and potential barriers and opportunities related to a trading platform for system services, DER and demand response (DR), scheduling of storage, and short-term hedging and co-ordination.
2. Detail of how each option described in Section 7 facilitates meeting the objectives in the context of each other and the various use cases.
3. UCS overview.
4. Trading in an ahead market.
5. Ahead market strawman.

1. Context

Market Reform was engaged by AEMO to provide advice on the design elements, and content in this paper has been developed in consultation with Market Reform and the Scheduling and Ahead Markets Technical Focus Group.

The use cases that are being examined through this initiative include:

- Activating additional system services for market benefits.
- Establishing a platform to hedge system service costs.
- Facilitating greater DER and DR participation.
- Improving scheduling of storage.
- Providing a new mechanism to hedge against short-term variability.
- Improving coordination between electricity and other markets (e.g. gas and electric vehicles).

Below is a brief discussion on the potential barriers for these use cases in the current framework and the opportunities available for these use cases.

Trading platform for system services

As described in the main document, system services that were once provided implicitly with energy generation by synchronous generators are no longer necessarily provided as a “free by-product”. There are numerous implications for this with respect to the dispatch and pricing of the system, including:

- The system services required for the secure operation of the system are required to be separately defined and valued such that they can be explicitly dispatched.
- The resources providing the system services need to be co-ordinated and scheduled, and this problem is becoming more complex with the changing heterogeneity of the technology.
- The relative value of system services is likely to increase, and thus may benefit from different options for management of the risks associated with delivery and the cost of provision. Incentives for self-commitment will be retained with valuing the services and enabling contracting against the price of that service, with an ahead platform providing an avenue to manage this commitment and associated risks.

- The level of system service provision can directly impact how much energy can be provided by certain resources; ultimately impacting the total system cost and potentially leading to an inefficient outcome if not able to be managed.

Where these resources are providing shared services, there is not a direct relationship between suppliers and customers providing those services, as there is with energy, and appropriate mechanisms should be in place to commit and schedule these resources. In these cases, it may be appropriate for a central buyer to buy those services on behalf of the market, as discussed in the ESS chapter (Section 6). With clear ex ante allocation of those costs, it may be possible to allow participants from both the supply and demand side to procure those services, with a platform to hedge their revenue and price exposure risks. An ahead mechanism is a potential option to improve the scheduling efficiency of these services and allow participants to manage their risks.

An ahead mechanism also provides a potential platform for the activation of system service provision above the minimum levels for secure operation. This may contribute to the ability to alleviate constraints in the system and allow more lower-cost energy provision overall.

DER and demand response

In order to efficiently integrate high and growing volumes of DER into the grid systems and capture more value of the demand side, there is a need to consider their participation in the dispatch framework. Some demand response and DER resources currently face barriers to participate in the current market framework due to:

- Long notification time.
- Inflexible operational characteristics (e.g., min-on/off or lumpy output level).
- Uncertainty of value received via changing consumption profile.
- Coordination complexity and inability to respond to real-time price signals resources in the distribution network.

The commercial risks presented by these barriers cannot be fully hedged by participation in the forward contracts market. Consequently, the ESB has received feedback from some demand response providers that a greater level of certainty over the commercial returns ahead of time would improve the ability and willingness of some consumers to make their load flexible. Loads are flexible at different timescales. While some loads are very flexible at short notice, others need to prepare their operations. The lack of confidence that the prices will not eventuate presents a barrier to their consideration of disrupting the operation of their core business, leading to a current lack of interest in participating in the wholesale electricity market.

The ESB has similarly heard that the current NEM is deficient in its consideration of the role of DER today and that DER participation and value can be derived through ahead markets, and improved/automated cross-market coordination. Relevant to dispatch is stakeholder feedback that DER are multi-class assets and can have very slow activations and ramps and very fast ramps so market constructs at different timescales will lead to increased participation and thereby more competitive markets. Also relevant is that, in general, DER are largely distribution connected and, operationally, higher visibility and advanced notice will allow networks to better operate and utilise DER to drive lower infrastructure investment, enabling value stacking for both network and wholesale markets allowing DER assets to be properly scheduled (e.g. charged in the case of storage) for both markets.

Scheduling of storage

Storage is projected to become an increasingly important and prevalent part of the resource mix of the NEM. Different storage resources have the ability to provide different services at different timescales. For example, some storage utilises synchronous technology, and can operate in various modes, while others are connected via inverter-based technology and can respond very quickly to changing conditions. Different storage technology can also be classified as having various depth of storage – deep to shallow – corresponding their energy storage capacity, and having different requirements for resource management.

Stakeholders have indicated that consideration needs to be given to how best to manage these resources in a complex and uncertain environment with competing needs and priorities, and ensure that the market design incentives align with the needs of the power system and ultimately consumers.

Short-term hedging and co-ordination

Finally, an ahead mechanism presents an opportunity for participants to fine-tune their hedge position against the expected physical conditions closer to the day, and co-ordinate their participation in the electricity market with their activities across other sectors. While the AEMC recently made a Rule change determination not to progress with the Short Term Forward Market Rule Change[1] to introduce a platform for short term energy trading, the potential presented and examined under this initiative differs as it is considers the management of system services and co-ordination of resources in the dispatch timeframe.

[1] https://www.aemc.gov.au/rule-changes/short-term-forward-market

2. Summary of options

Table 1 Summary of how options (from consultation paper Section 7) facilitate meeting objectives

Objective of design		UCS-only	System services ahead scheduling	Integrated ahead market	Compulsory ahead market
Enhance reliability and security	Resource available when needed Early identification of risks Better process to address system gaps	In a more variable and uncertain operational environment with greater operational risk to the system, AEMO has an enhanced tool to identify, communicate and address system service shortfalls. Where the service is covered by non-market system security service contracts held by AEMO or TNSPs (e.g. for system strength and inertia), the UCS facilitates identifying the optimal mix of contracts to call. Provider commits contracted units called giving the market visibility. Where system security requirements are not met, AEMO resorts to directions processes as it does today and uses the UCS to support this process.	An ahead market based on firming up system service provision for the operational forward period could have additional efficiency benefits: • For the market, if it leads to less out-of-market interventions through the UCS. • For AEMO, as control room and operations planning staff will have a higher level of confidence that the resource availability in PDS will meet system services, be more firm if backed by an ahead schedule that aligns with physical conditions and less likely to shift unless changes in system conditions require it.	In the dimension of enhancing reliability and security, an ahead market based on firming up system service together with energy positions for the operational forward period would have similar benefits to option 2 but with the additional benefit of reducing the uncertainty of the energy price when providing system services with resources that will necessarily also produce energy. If an ahead market also unlocks additional resources, e.g. demand response and DER, it will have more options for meeting reliability and security needs. Additionally, if it leads to an improved system-level schedule of energy storage, it can contribute to reliability and security by reserving storage for periods with high security and reliability value or where the uncertainty is greatest.	An ahead market based on physical commitment is likely to introduce inefficiencies and could even potentially detract from meeting security and reliability if participants cannot deviate away from their ahead schedule even when conditions change between the ahead market and real-time.

Objective of design		UCS-only	System services ahead scheduling	Integrated ahead market	Compulsory ahead market
Improve scheduling efficiency and lower costs to consumers **Facilitate the transition in generation mix, consumer engagement, and DER integration**	Activate additional system service for market benefit	While a process to activate contracted system service resources for market benefit (above minimum security requirements) is being explored, it appears unlikely to be viable with a UCS only option as it would likely be complex and rely on an ex ante estimation of the value of reducing curtailment or achieving other market benefits based on pre-dispatch bids that are not firm.	System services under this option would be able to be traded and procured for market benefit, especially when two-sided traded is considered, but this may be limited by the lack of integration of services and energy. It may, again, be challenging to form a demand curve for additional system services to reduce potential curtailment or achieve other market benefits if these benefits are related to the value of energy where this would influence participants' willingness to pay for the service.	An ahead market can coordinate the resource mix and provide a platform for participants to procure system services to improve dispatch efficiency via a market mechanism. It could offer a mechanism for those parties that would benefit from additional system service provision to express their willingness to pay and secure those services. An integrated ahead market has the most potential for delivering this objective.	An ahead market can coordinate the resource mix and provide a platform for participants to procure system services to improve dispatch efficiency via a market mechanism. A mandatory and physical platform would ensure participation levels in the ahead timeframe and would enable a coincident assessment of the costs of additional system service provision against the benefits to relieving constraints on some plant or network.
	Platform to hedge system service costs	Not applicable – the UCS is not a platform that will facilitate trades between participants.	An ahead market where system services can be traded can provide a mechanism for participants to hedge their system service costs so long as costs are transparently allocated.	An ahead market where system services can be traded can provide a mechanism for participants to hedge their system service costs so long as costs are transparently allocated.	A physical ahead market is unlikely to provide this hedging platform as there is no longer a financial commitment associated with the provision of the services, but instead a physical commitment.
	Facilitate greater DER and DR participation	Not applicable – while the UCS will have to factor in the impact of DER and DR in analysing the system, it will not in and of itself facilitate participation by those resources.	Some DR and DER resources have long notification time and lumpy characteristics. Uncertainty and risks in the RT-only market might restrict their ability and willingness to participate, where an ahead market for energy could facilitate this.	Some DR and DER resources have long notification time and lumpy characteristics. Uncertainty and risks in the RT-only market might restrict their ability and willingness to participate, where an ahead market for energy could facilitate this. This option would be expected to increase the participation of DR	An ahead market in option 4 facilitates opportunities for DER and DR but stricter compliance obligations may present a barrier to participation.

Objective of design		UCS-only	System services ahead scheduling	Integrated ahead market	Compulsory ahead market
			To the extent demand and DER resources can provide system services, an ahead market for these services may increase participation from these resources as they can have certainty in these value streams and time to organise their operations to provide the service.	and DER resources further than option 2, as these resources would now participate in energy and lock in the price for that as well as system services.	
	Improve scheduling of storage	While, as an intertemporal optimisation, the UCS may be able to better interpret storage levels over the horizon, it will not directly influence or facilitate a schedule for those storage participants.	An ahead market for system services may contribute to storage systems able to co-ordinate their provision of system services.	Storage faces unit commitment decisions associated with managing their state of charge; these can be managed through an intertemporally-optimised schedule provided in an integrated ahead market aligning the charge and discharge with highest value periods – incorporating both the value of energy and services (including the value of keeping some reserves for periods when reserves are highly valued).	Storage faces unit commitment problems associated with managing their state of charge; these can be managed through an intertemporally-optimised schedule provided in a compulsory ahead market, however less flexibility to move away from this schedule as real-time conditions change may lead to inefficient results and the design would need to consider how to incorporate sufficient flexibility to allow this to occur in a physical commitment ahead framework.
	New mechanism to hedge against short-term variability	Not applicable – the UCS is not a platform that will facilitate short term trading of energy.	An ahead market just for system services will not provide a platform for short term trading of energy.	Increasing variability and uncertainty potentially might lead to greater need to re-tune contract or portfolio positions to better align with real-time operational need for participants; an ahead market where energy is traded allows for this at a time when forecast conditions are better known than	A compulsory, physical-commitment ahead market will instead move trade to that market, and minimise the ability to change position between the ahead market and real-time timeframes.

Objective of design		UCS-only	System services ahead scheduling	Integrated ahead market	Compulsory ahead market
				when the longer-term hedge contracts were struck. Being financially binding, it retains the ability to move away from these positions if a change in conditions as we approach real-time makes it beneficial.	
	Better coordination between electricity and other markets	Limited applicability – while the UCS will allow market participants and the system operator to have better visibility of the expected system conditions and potential interventions, it will not facilitate co-ordination of those other market processes directly.	Ahead market that facilitates a schedule for system services may help to coordinate those resources that are also participating in other markets (e.g. GPG). However, the spot price for electricity is not locked in at the time.	An ahead market for electricity naturally aligns with daily gas markets, and could provide additional certainty for participants with gas portfolios to manage their resources. Similarly, there may be alignment with the daily schedules for other markets where electricity is an input, e.g. DR and EVs.	An ahead market for electricity naturally aligns with daily gas markets, and could provide additional certainty for participants with gas portfolios to manage their resources. Similarly, there may be alignment with the daily schedules for other markets where electricity is an input, e.g. DR and EVs. It receives a lower rating than option 3 again for the added complexity of needing to manage physical deviations from the ahead schedule which would be required to manage shifts in the other markets as well as in the electricity market.

3. UCS overview

This section provides additional information on current thinking for the high-level design of the UCS process and tools.

The information provided here is in the context of the UCS in Option 1, UCS-only, such that the UCS can be used to:

1. Schedule non-market system security contracts held by AEMO or a TNSP (e.g. for system strength and inertia).
2. Where system security or reliability gaps exist, support identification of last resort interventions more efficiently and transparently.

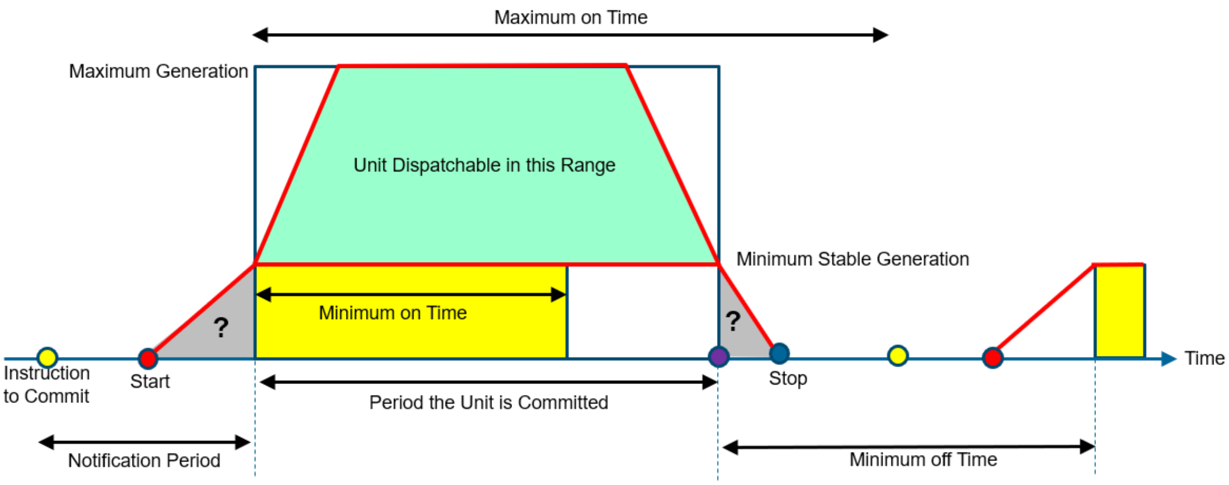
This information was presented to and discussed with the Technical Working Group in May and has since been refined based on feedback and further development.

Before discussing the UCS itself, we briefly discuss the unit commitment problem and what the UCS tool would be aiming to achieve.

The solution to the unit commitment problem determines which resources should be turned on when, in order to meet the total system requirements in an optimised manner (e.g. lowest cost). Determining which resource to turn on when is complicated by constraints such as:

- How fast each unit can react to an instruction?
- What is the unit's minimum stable generation, and how soon can it reach that level and at what rate?
- How long does it take to reach maximum output and at what rate?
- What is the minimum duration for the unit to remain on?
- What is the minimum wait time to restart the unit if is turned off?

FIGURE 1 TYPICAL GENERATOR UNIT COMMITMENT CONSTRAINTS



The unit commitment problem can also take a pre-determined unit commitment solution as an input, and adjust from this if necessary to meet the system requirements, optimising across the whole range of requirements and resources.

These constraints are non-linear and binary in nature. While they cannot be handled through a linear optimiser such as NEMDE, they can typically be handled through the well-developed technique of mixed integer programming.

Unit commitment problems typically optimise the solution over a time horizon. By taking into account costs for making the unit commitment decisions (i.e. start-up, minimum generation and variable costs), the unit commitment problem can trade off between starting units that have different technical requirements. That is, by optimising intertemporally, it can make a meaningful choice between, for example, starting inflexible resources with high start costs but with lower ongoing cost compared to starting a flexible resource with a lower start cost but more expensive running cost.

Inputs

Input	Provider	Use	Regularity of provision	Notes
System forecast	AEMO	To define expected demand and VRE generation, system service requirements	Latest forecast information available will be used.	This information may also feed into sensitivity analysis whereby the UCS could be run with different inputs to account for uncertainty.
Network information	NSPs / AEMO	To define the network information including constraints and outages for the assessment.	Latest network information available will be used.	The UCS is able to use more granular data if available than pre-dispatch as an out-of-market analytical tool, rather than dispatch tool.
Plant technical data including notification time, min on/off time, min-gen, ramp rate, energy storage limit	Participants / AEMO	To be used in finding the optimal unit commitment to meet the system requirements where additional commitments are required compared to those self-committed by the market.	This could be provided as standing data and updated as required. Ideally provided through a standardised system, rather than ad-hoc communication.	The additional unit commitments could involve bringing online an additional resource or preventing a resource from desynchronising.
Pre-dispatch	AEMO	To define the unit commitment indicated by market participants (i.e. the self-commitment schedule).	Latest PDS will be used each time the UCS is run.	Where there is also an ahead market, it can be expected that participants will reflect their ahead market schedule in their real-time (pre-dispatch) bids.
Contracted system services	AEMO, TNSPs or providing participants	To be used to determine when and which resources are to provide required system services.	Could be reflected in unit technical and economic information.	How this information is provided and what form it is required to be provided in will depend on the system service and procurement method.
Plant economic costs – which could include start up, no load and incremental variable costs	Participants	To be used in determining the least-cost directions where required to address gaps in system requirements that were not able to be met through market or contracted system services.	This could be provided as standing data or updated more regularly depending on the conditions of the day.	Some stakeholders have expressed concerns with providing this information as it can change depending on the conditions of the day and may not always be able to be accurately provided. These details will continue to be developed in upcoming design phases.

Optimisation

As an inter-temporal, mixed-integer optimisation, the UCS can assess non-linear system requirements such as those associated with the technical requirements of generation units including commitment times and ramping constraints, as well as those associated with the requirements of the system itself, such as combinations of unit commitment that lead to different levels of system strength, for example. The optimisation for the UCS would be to minimise the total cost of committing and running units over the operational horizon, subject to the following sets of constraints:

1. Energy demand = supply.
2. System services demand and constraints met.
3. Network constraints satisfied.
4. Generator output within technical limits.
5. Generator on/off (commitment) decisions feasible.

When the UCS is being used to schedule long-term contracts for system services, as in Option 1, contracts can be treated as if they are "notional generators" with plant costs and technical limitations reflecting the contract terms.

The UCS would use this optimisation when an adjustment to the unit commitment indicated in the pre-dispatch is required to address a system requirement, including an out-of-market commitment or to schedule a resource to provide a contracted system service. Even with a UCS in place, the principles of self-commitment will be followed with the commitment indicated in pre-dispatch the starting point. The UCS will not be used to override the self-commitment of participants unless required where there are potential shortfalls of services.

Note, the pre-dispatch schedule is not always feasible for all generators; participants rebid in the time leading to real-time to ensure their eventual dispatch is technically feasible. As such, there may need to be a pre-processing step to ensure the input commitment schedule is actually feasible. Rules and processes would be established at the time of implementation to facilitate this.

Output

When being used in Option 1 to schedule long-term contracts for system services, the output of the UCS will be to indicate the optimal scheduling of those contracts for the conditions on the day. This would indicate what resources should be scheduled to provide contracted services when, to ensure a minimum level of service provision across the day (if possible).

Otherwise, the typical output of the UCS when used as a decision-support tool for the AEMO control room will be to:

1. Flag if there are any gaps in system requirements as per the expected dispatch pattern.
2. Indicate the optimal way to resolve the system gap by finding the least-cost adjustment to the unit commitment, ensuring all system requirements continue to be met.
3. Potentially indicate "pivotal" units, which are those that have self-committed in the market but for which it has been identified that there will be a potential gap if those units decommit.

These results can be published to the market, making the intervention decision process more transparent.

Commitment instruction and contract activation

The output of the UCS would indicate the optimal solution, but it is proposed that it would still take an action from the system operator to act on the output of the UCS, at least in the initial stages of implementation.

It is proposed that, using the UCS solution as its basis, the system operator can either:

- Activate a contract with a unit that has been contracted to provide a system service, or
- Intervene in the market and direct a unit.

The timing for taking these actions is discussed below.

Compensation and settlement matters

It is proposed that the intervention pricing principles are consistent with current practice such that:

- Intervention pricing does not apply where the system operator activates a system service contract, as there is no real-time spot market for the service. The unit would be compensated as per the terms of their contract.
- Intervention pricing would apply for AEMO interventions (using the UCS or otherwise) as currently so long as that intervention is to provide a service that is priced in the spot market. The compensation for the out-of-market commitment would be as per current arrangements.

Timing

It would be expected that the UCS would run multiple times a day at regular intervals, each time assessing the remainder of the study horizon (e.g. pre-dispatch period). Each time the UCS runs, it takes the latest expected commitment schedule from the pre-dispatch outcomes as an input and compares that to the system requirements. In this assessment, the UCS can firstly identify potential gaps in system requirements and secondly identify the most appropriate action to take to address that gap by adjusting the unit commitment.

The UCS-only option (Option 1) would start by looking at scheduling of resources with pre-existing contracts for the provision of system services relevant to the identified gap.

Across all options, if there are insufficient resources either contracted or made available through market-based processes, the UCS would be used to indicate what interventions may be required. For gaps in spot-market-priced services, AEMO would continue to wait until the latest time to intervene, to allow for the market to respond.

Schematic

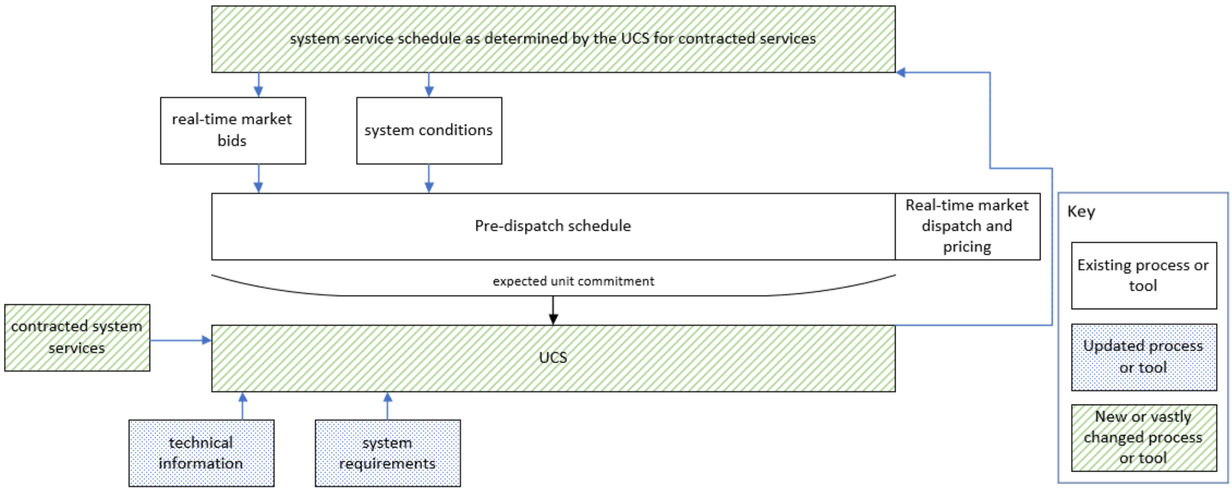
The schematics below show how the UCS operates under different arrangements:

- Panel A shows how the UCS can be used to schedule contracted system services in Option 1, UCS-only.
- Panel B shows how the UCS is used to assist in intervention decisions.
- Panel C shows how the UCS operates where there is an additional ahead scheduling process, as in Options 2 and 3. The next appendices further discuss how these ahead processes may function and interact with contracted system services and the UCS.

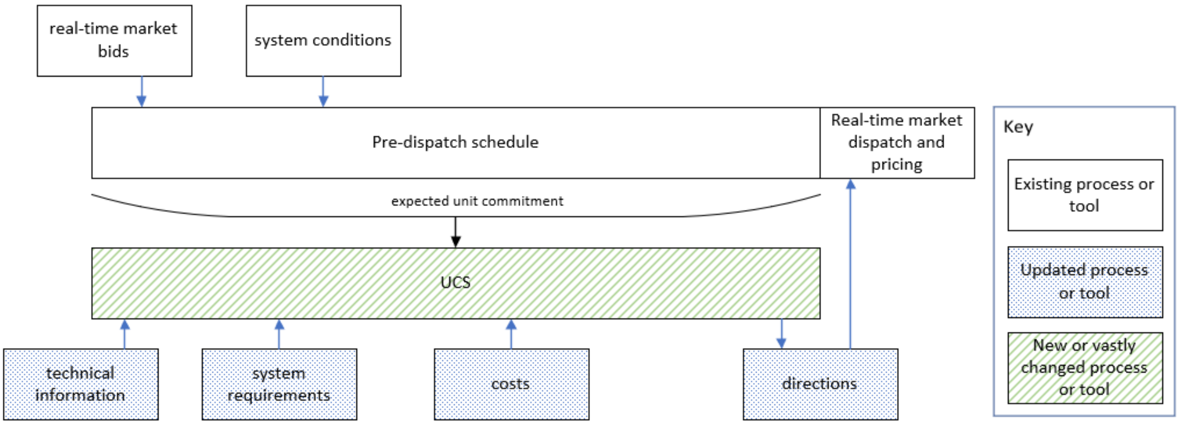
These schematics are intended to diagrammatically highlight the interactions between the processes, but do not show all interactions nor the timing of those interactions.

FIGURE 2 UCS SCHEMATICS

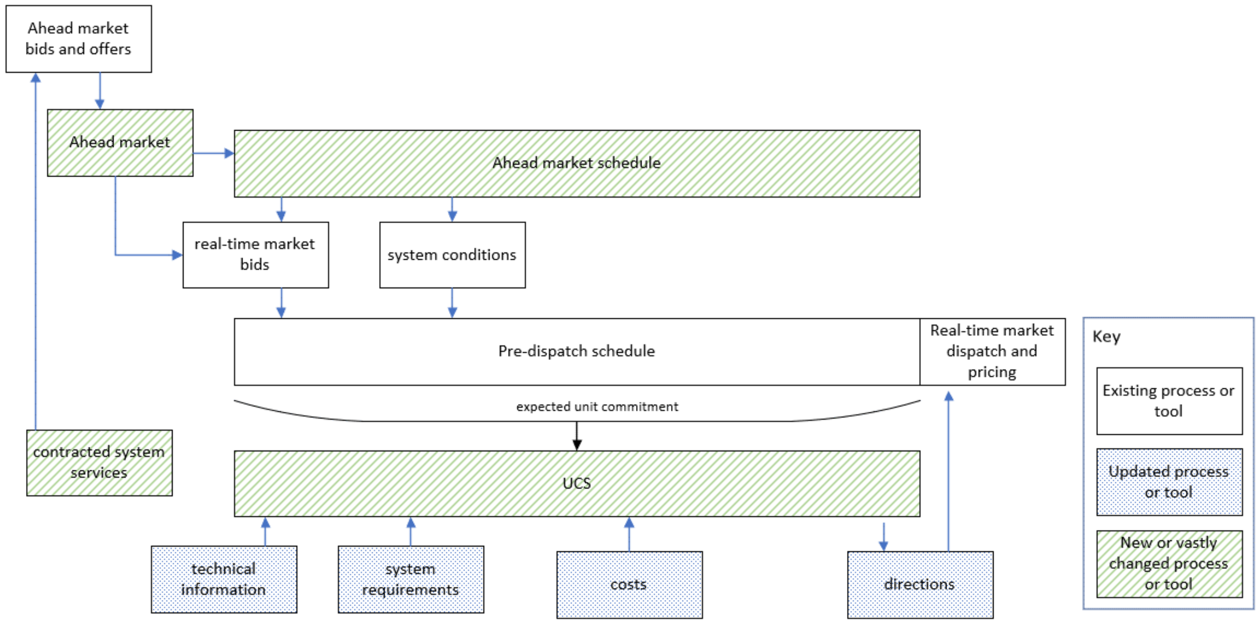
A



B



C



Ahead market bids and offers
Ahead market
Ahead market schedule
real-time market bids
system conditions
Pre-dispatch schedule
Real-time market dispatch and pricing
expected unit commitment
contracted system services
UCS
technical information
system requirements
costs
directions
Key
Existing process or tool
Updated process or tool
New or vastly changed process or tool

4. Trading in an ahead market

This section provides an introduction to how system services (and energy) with a real-time price may be traded in the ahead market.

First, we discuss what trading in a generic ahead market might look like. Then, we briefly refresh on what the purchase of system services looks like in a real-time only model. Finally, we extend the discussion to what the purchase of system services with a real-time market could look like under two different ahead market models: with AEMO as the central buyer in the ahead market, and with participants directly purchasing system services in the ahead market.

A generic ahead market

Trading in a financially binding ahead market is similar to the trading of a swap contract from a financial point of view. That is, when there is an ahead market, the settlement of a participant is calculated as:

$$q_{AM} \times p_{AM} + (q_{RT} - q_{AM}) \times p_{RT}$$

where q_{AM} is the participant's quantity in the ahead market schedule (where a positive quantity is an injection)

p_{AM} is the price in the ahead market schedule

q_{RT} is the participant's dispatched quantity in the real-time schedule (where a positive quantity is an injection)

p_{RT} is the price in the real-time schedule

The net effect of trading in an ahead market is that deviation from the ahead market schedule is settled against the real-time price.

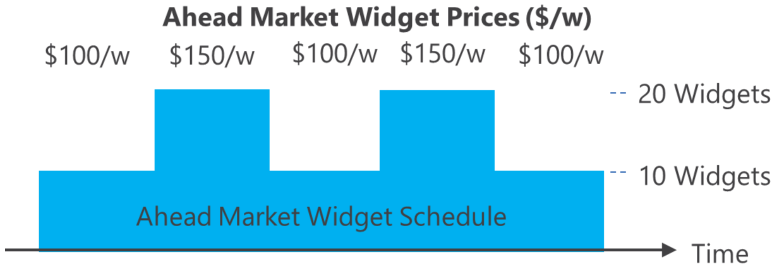
The ahead market also provides an operational schedule for the units which trade in the market. The operational and settlement dynamics are demonstrated in the example below of an ahead market for widgets.

A widget maker is competing with others to supply widgets to a demand that will vary by period throughout the day. The widget maker in question has a contract position to cover for supply widgets. It must plan a day ahead how it will run its machine for the following day, and must buy fuel to cover that plan. Consider that the widget maker machine costs $1000 to start and once running, it costs $80 per widget. Once on, the machine can supply at a minimum of 10 widgets and at most 20 widgets per period.

In the ahead market, the widget maker offers with an expectation to run for 5 hours at an offer of:

10 widgets at $90/widget, and a further 10 widgets at $120 / widget.

The ahead market schedule for the widget maker is set as follows:



The income for the widget maker from its ahead market schedule would be $9,000 (3 periods producing 10 widgets for $100/widget, 2 periods producing 150 widgets for $150/widget).

The expected costs for the widget maker are equal to $6,600 (start cost of $1000 plus 70 widgets at $80 per widget).

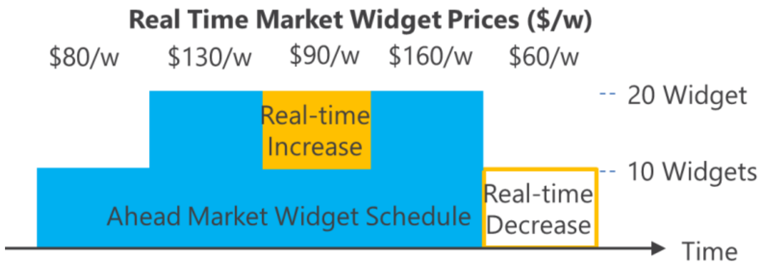
As such, the widget maker can expect a profit of $2,400 from the ahead market.

The ahead market facilitates trade between buyers and seller who are happy with the price in the ahead market. If they follow this schedule exactly, they can be sure to receive this profit.

However, in the real-time market, the widget maker can choose to deviate away from its schedule if it is profitable for it to do so.

When the widget maker makes its offer into the real-time market, it can make this offer to supply at its $80/widget running cost for all 20 widgets as it has already recovered its $1000 start-up costs in the ahead market.

In the real-time market, with this offer, it is scheduled to provide 10 more widgets in period 3, but lower prices in period 5 reduce its schedule by 10 widgets to zero.

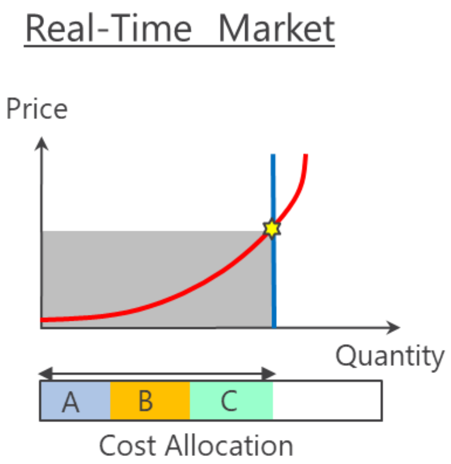


The widget makers' income in the real-time market is calculated as per it's deviation away from its ahead market schedule. This equates to $300 ($90 / widget for 10 widgets additional in the 3rd period less $60 / widget for 10 less widgets in the 5th period). While the widget maker has additional running costs in period 3 compared to its ahead schedule, it has less running costs in period 5, and these even out. This translates to an additional profit for the widget maker of $300 dollars to reward it for its flexibility in the real-time market.

Real-time market for system services

In today's NEM, FCAS is a system service which is purchased in the real-time only market. Procurement of FCAS in today's real-time only market can be described as follows:

- AEMO sets a discrete requirement (which can be represented as a vertical demand curve) to be procured in the market.
- Participants who can supply the service submit discrete offers to supply the service.
- AEMO buys the lowest cost offers in real-time to meet the discrete demand, and clearing price is set.
- The service supply is co-optimised with energy and other FCAS services, and only that which is technically feasible is cleared.
- AEMO allocates the costs associated with the purchase of the service to participants.



If other system services are introduced for which a real-time price can be formed (e.g. operating reserve), it can be assumed a similar process will be followed.

For the purpose of this appendix, an assumption is made that sophisticated demand curves will not be introduced into the real-time market, such that the purchase of system services in the real-time market will always be at a discrete requirement. We also assume a real-time market exists for the services discussed in the following section.

An ahead market may also be utilised for system services that do not have a real-time market; eg. for synchronous services for which the formation of a real-time price may be difficult. While we don't discuss the ahead market design for these services in this appendix, similar design philosophy would apply but further consideration needs to be given to what it means to have a financial commitment; this is a key area for further development in the ESB's next phase of work. The material presented here is to provide some further background for interested stakeholders to facilitate engagement in the development of ahead mechanisms for the NEM.

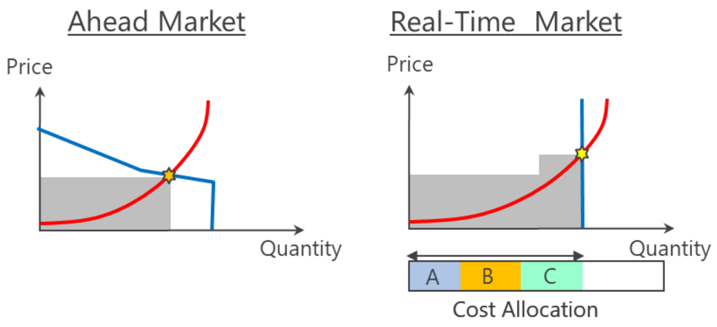
Ahead market for system services that have a real-time market

The introduction of an ahead market would facilitate the trading of system services in an ahead timeframe, potentially increasing the number of resources that can provide the service by providing a fully-funded ahead market award on which they can act.

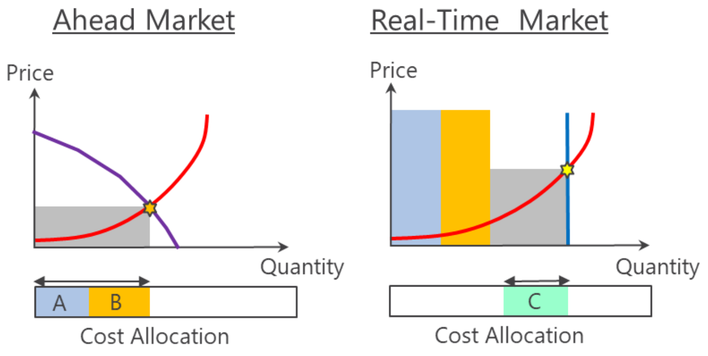
Participants are incentivised to offer into the ahead for the system service to secure an award to provide the service ahead of the time they would be providing the service. In this way they can arrange their operations with such an award in mind. Also, where long-term contracts for provision of the system service are established between AEMO or NSPs under a structured procurement framework (as discussed in Section 6), this may be linked to participation in the ahead market.

There are options for how the demand for the system service in the ahead timeframe can be set:

- *AEMO is the central buyer* – under this option, AEMO would buy services in the ahead market in accordance with an administratively set demand curve for the service. The demand curve would be set through a regulatory process (as discussed in Section 6). AEMO would still purchase the full requirement in real-time, however the costs would be offset by purchases made in the ahead market. AEMO would allocate the total costs to the relevant participants.



- *Two-sided market* – under this option, participants that will bear the system service costs would be able to manage their exposure by directly purchasing the system service in the ahead market. AEMO would ensure the total service requirement is procured in real time, but the net effect would be that any additional costs in the real-time market would be allocated to those who have not procured the services directly in the ahead market. This option requires participants to have a clear understanding of their potential cost allocation in the system service market and may require the cost allocation processes for services to be revisited (e.g. the causer pays allocation for regulation FCAS may not be amenable to this option in its current framing, since it can be considered to be quite complex and participants may not have an understanding of their obligations until after the fact).



Under either option, a participant who has cleared to supply in the ahead market would need to offer to supply the service to the real-time market in order to be dispatched. If they are not scheduled to supply the service in the real-time market (either because they do not offer or their offer price is too high), they would have a deviation from their ahead market schedule, and be required to pay the difference at the real-time price. This is the basis for a financial commitment in the ahead market.

Note that the clearing of system service offers in the ahead market can also be co-optimised with the provision of energy and/or other system services.

Example of trading system services in the ahead market

The following example was presented to the Technical Focus Group to support stakeholders in understanding how an ahead market for system services may work. The example is presented here to provide context on the possible design of an ahead market for the NEM.

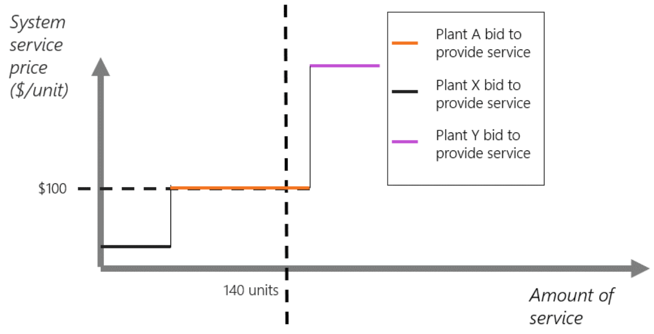
In this example, consider a system service for which a real-time market can be established, and the cost allocation for the system service is clearly understood by participants. In this example, consider that there is only one retailer that will be responsible for purchasing the entire the system service requirements in real-time market. The retailer can manage this procurement risk in part through trading in the ahead market. The price for the system service is set at the marginal price. For simplicity, we do not consider co-optimisation with energy in this example.

The requirement for the system service is set at 140 units of system service by AEMO.

There are three plants in the system that can provide the system service, each with different costs and technical constraints associated with providing the system service:

- Plant A can provide 100 units, at a marginal price of $100/unit.
- Plant Y can provide 50 units, at a marginal price of $200/unit.
- Plant X can provide 50 units, at a marginal price of $10/unit.

If each plant offers into the real-time market at its marginal price, the price for the system service will be set at $100/unit, by Plant A.

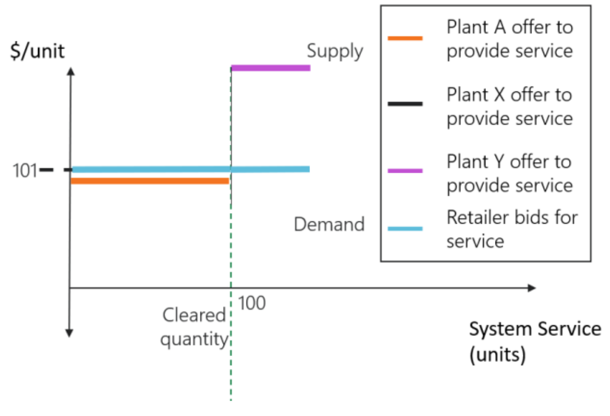


However, consider that Plant X could have an outage in real time. In this case, the system service price will be set by Plant Y, at $200/unit. In this scenario, the retailer will be exposed to these higher prices, without an ability to protect against this exposure.

Now consider the case where the system service is traded in the ahead market on a two-sided, voluntary basis. The retailer knows they will be required to fund 140 units of the system service in the real-time market, and they expect the price to be $100/unit. They can bid in the ahead market to secure a price for the provision of the system service. They choose to bid at $101/unit for all 140 units of the service (they are prepared to pay a small risk premium to lock in this price in the ahead market).

In the ahead market, Plant X does not participate. Plant Y and Plant A bid at their marginal prices; $200/unit and $100/unit respectively for their full capacity.

As such, 100 units of the system service clears in the ahead market at a price of $101/unit, with Plant A receiving an ahead schedule to provide this service.



In the real-time market, all units are still required to offer their service in to be dispatched to provide the service. They each still offer at their marginal price, and the real-time market clears as before. However, now if Plant X has an outage, the retailer is only exposed to pay $200/unit for the remaining 40 units that it did not secure in the ahead market.

While under this scenario Plant A would have a reduced overall revenue given the outage of Plant X occurred, the ahead award can give it the certainty to commit to supply service in the ahead market. In this scenario, the retailer and Plant A could trade away their risk. In cases where there was no outage, Plant A would have received a slightly higher revenue overall due to the risk premium the retailer is willing to pay in the ahead market.

If Plant X had participated in the ahead market and also received an award, it would have been responsible for paying for the undelivered quantity after its outage at the higher real-time price. As it was, it received revenue from the real-time market just for the hours it is online.

5. Ahead market strawman

This section outlines a potential strawman design for an ahead market for the NEM to facilitate stakeholder understanding and discussion. This section highlights the design elements and potential options of the elements of an ahead market design (Option 2, Option 3, or somewhere in between).

Products

The ahead market can facilitate procuring, trading, and scheduling of energy and/or system services.

System services can be broadly separated into two categories:

- Those which do not have a real-time spot market, and which are instead procured under a structured framework. The ahead market is used to assist in scheduling those services. For example, system strength, which is provided by synchronous resources being online.
- Those which do have a real-time spot market, e.g. the existing FCAS services or potential new services that require the provision of some headroom (often referred to as operating reserve). The trading of these system services in an ahead market has options associated with whether the services are procured under a two-sided market, or with AEMO as the central buyer, utilising demand curves.

In this strawman design we discuss the potential for an ahead market with or without energy.

There is also the potential to include other more bespoke products to be traded in the ahead market, including distribution level services which can be used to assist in the scheduling of DER or DR. For simplicity, we do not consider these functions in this strawman design; consideration of these types of functions will occur in a subsequent phase in conjunction with the two-sided market and DER integration workstreams.

Participants

This section outlines who may participate in the trading of products in the ahead market; this is not to indicate the regulatory participation categories.

Participant category	Participation	Products
Generators (any energy provider)	Voluntary	Energy – natural suppliers System service – may be suppliers or buyers to hedge the costs of system service provision allocated in a two-sided market.
System service providers (e.g. synchronous resources)	Voluntary or as per the terms of any long-term contracts for system services	System service – natural suppliers
Demand (retailers and large customers)	Voluntary	Energy – natural buyers System service – buyers to hedge the costs allocated in a two-sided market.
Demand response providers	Voluntary	Energy – natural buyers – allows for scheduling their resources to consume demand in a pattern where they can lock in a price for consumption ahead of time, or revenue for providing demand response, and coordinate accordingly. System service – some applicability in current framework where demand response can provide FCAS. There may be more

Participant category	Participation	Products
		applicability in the future; for example, where flexible demand response providers can supply system services an ahead market could assist in scheduling their resources to do so.
Storage	Voluntary	Energy – natural buyers and sellers – an ahead market can be used to facilitate scheduling of storage providers, ie. the charge and discharge patterns, guaranteeing a minimum revenue for example. System service – in the same way the ahead market can be used to facilitate the scheduling of storage for energy, so it can be used to facilitate the scheduling of storage to be at the appropriate state of charge to provide system services where applicable.
DER and aggregators	Voluntary	Energy – natural buyers and sellers System services – an ahead market may enable DER providers to structure their response to participate in the system service markets.
Network service providers	Where applicable	Energy – limited applicability System services – may be a supplier either through contracted services or owned assets.
Virtual traders	Voluntary	Energy and system services - optional design feature to allow virtual traders to participate in the market. Typically included to facilitate arbitrage between the ahead and real-time prices – ultimately reducing the difference between the real-time and ahead prices. Any virtual trades must be closed out in the real-time market.

Trading and scheduling

a) Financial scheduling

Where a product has a real-time spot market, the ahead market awards are expected to be financially-binding. This means, if a participant deviates away from their ahead schedule they will be required to pay for (or be paid) the deviation at the real-time price. In this way, the commitment is considered to be financially-binding; if they directly follow their ahead schedule they will be paid (or pay) at the ahead market price.

Where a product does not have a real-time spot market, there needs to be further consideration of what it means to have a financially-binding commitment. It could be that the participant that does not follow their ahead schedule is exposed to any costs for the system operator needing to intervene and bring on any other resource to fill any gaps that may be left due to that participant not following their schedule. Alternatively it may just mean they miss out on receiving their ahead market award, with implications for system security and the efficacy of the market design to be considered.

b) Bids and offers in the ahead market

Types of offers

In a simple implementation, only incremental price-quantity bids and offers similar to the current NEM could be accepted. In this approach, participants would implicitly reflect their start-up and other non-incremental costs in their incremental price-quantity bids. Depending on the complexity of the scheduling mechanism, they may also need to reflect other physical limitations such as minimum on and off times in their incremental offers (just like in the NEM today).

However, it may be beneficial to allow physical participants to submit three-part bids to the ahead market optimisation, which include not only an incremental offer per MWh but also a start-up (cost per start-up) and minimum-generation (e.g. cost per hour) component. Three-part bids typically go hand-in-hand with corresponding technical commitment constraints of the units, such as minimum run times, and minimum off-times. This allows the optimisation process to explicitly consider different cost and physical structures of different resources. This can ensure that the participant's schedule is technically feasible over the scheduling horizon.

When a feature like three-part bids is included in the design, typical implementation would be to also include uplift payments to ensure resources recover the total cost of their operation across the period of trading. However, this is not a necessary design feature as outlined in the "compensation" section below. It is also important to note that participants would not be required to make use of this kind of feature even where it is included – they could still participate in the ahead market using incremental bids and manage their own commitment schedule.

There are also other sophisticated bidding options which an ahead market with an intertemporal optimisation could facilitate. For example, minimum revenue offers could be used whereby an offer would only clear if it had secured a minimum revenue over a particular period of time, also considering physically feasible constraints.

System services

Demand (bids):

- Where a two-sided market is established, participants would submit price-quantity bids for the system service.
- Where AEMO is the central procurer, the bids for the service would be set through an administratively determined demand curve.
- There may also be the potential to combine the two processes, whereby the demand curve could be formed through bids from buyers as well as administratively set bids.

Supply (offers):

- Participants can provide offers to supply the system service. Further consideration is required for how offers for system services would be structured if the design integrates with an energy and other system service ahead markets. There is also a need to consider the design of offers for system services that may not have a real-time market.
- Where there are long-term system service contracts, the counterparties to those contracts may be required to offer into the ahead market – the terms of the contract will dictate how those offers are to be made.

Energy

Where energy is included in the ahead market, participation is expected to be voluntary from both the supply and the demand side.

Sophisticated bid/offers could be considered for storage participants for the ahead market to schedule the charge/discharge of the participants, where they could set the minimum price differential and technical constraints.

c) Basis of Ahead Market Pricing

Pricing should be on the same basis as the real-time market, such that if locational marginal prices are adopted under the Coordination of Generation and Transmission Investment (COGATI) reforms, energy and system services in the ahead market should also be priced locationally. Elsewise, pricing in the ahead market can similarly be done with respect to the regional reference price, just like the real-time market.

d) Operational and network constraints

The ahead market should be modelled consistently with the formulation in the real-time market to align with the representation of the physical system, but there is a range of options to dictate how sophisticated this representation can be. While the ahead market scheduling cannot take into account what the actual state of the power system will be in real-time, options for representing the physical system in the ahead market include:

- Ignoring intra-regional constraints entirely in the ahead market scheduling. While this is the simplest option, it would lead to the greatest divergence between the ahead market and real-time market as physical constraints would not be considered.
- Only applying a core set of constraints to approximate the envelope of operation defined by the real-time market constraints, but not exactly reproducing them. The rationale for simplifying the constraint sets used in the ahead market is discussed below.
- Include essentially all constraints of the real-time market model with the trigger of the constraints based on forecast or expected conditions. For example, constraints could be triggering in response to the levels of generator output of inter-regional flow in the ahead market solution, or through running a power system model. This is likely to improve the ahead market solution to be closer to that of real-time but with corresponding complexity of solver and maintenance.

These options will be considered under the detailed design phase. There is a trade-off to make in terms of design; while a simpler design is likely to be easier to implement, it may also produce a less effective ahead market solution. The way constraints are incorporated in the ahead market will also depend on which products are included in the ahead market design and the intention of the ahead market. For example, if energy is not included as a product to be traded in the ahead market, and the system services that are traded are at a regional or NEM-wide level, then there will be no need to include intra-regional constraints.

The modelling of constraints in the ahead market is also likely to be directly related to the level of participation in the ahead market. Under a voluntary participation design, it is evident that there may be less constraints binding in the ahead market with less than 100% participation. Under a voluntary, financial commitment design, it would be up to participants to manage this risk when participating in the ahead market, receiving an ahead schedule and then defending this in the real-time market.

As outlined in the Pricing section, if a network model is adopted under the CoGaTI reforms then the ahead market would also consider a network model.

The treatment of inter-regional constraints is also directly related to the adoption of the CoGaTI reforms. If CoGaTI is not adopted, consideration will need to be given to the Settlement Residue Distribution (SRD) units purchased in Settlement Residue Auctions (SRA), and how these relate to the ahead and real-time timescales.

e) Granularity

As an ahead market only produces a financially binding schedule, rather than being used to physically commit and dispatch units, it can clear at a lower granularity than the real-time 5 -minute market. This is to account for less granular information being available at the ahead market timescale compared to in real time.

f) Time horizon and timing

An ahead market would be designed to intertemporally optimise across a time horizon. In order to align with daily schedules of other markets such as gas, as well as diurnal patterns of resources, an ahead market could consider a time horizon of 24 hours.

The first ahead market run (see intraday section trading below) could occur the day before the trading day and could align with the timing of other markets; for example, gas trading activities.

g) Intraday trading

With the introduction of an ahead market, there can also be intraday trading opportunities established to allow participants to incrementally adjust their position in the lead-up to real-time. Intraday trading also means that participants can choose when they would like to participate in the ahead market.

Intra-day auction runs can be expected to replicate the ahead market, each one contributing to a balancing position in the lead-up to real-time.

Intraday trading allows for different resources that have different timing requirements participate in an ahead market and provides an opportunity to adjust positions between the ahead market and real-time market. This also allows participants to choose to take part in the ahead market at the time that suits them the best.

Exchange-based continuous trading can be an alternative way to facilitate intra-day trading between an ahead market and real-time and is used in other implementations. However, given the focus of ahead scheduling for the NEM is associated with scheduling system services and co-optimising these with energy, this is not a feature we are actively investigating for this design.

Pre-dispatch and real-time scheduling

With the introduction of an ahead market, the real-time market would continue to set the dispatch for the system. Pre-dispatch would continue to play an important role in providing an indication of real-time dispatch.

Participants would be expected to bid in real-time dispatch (and pre-dispatch) in such a way that they are able to follow their ahead market schedule, or to deviate away from this where applicable.

Interaction with the UCS

With an ahead market to schedule system services, including contracted system service resources, the UCS would be a backstop measure to provide the system operator a decision-making support tool for potential interventions. The UCS would be expected to continue to use the pre-dispatch schedule as an input to determine the expected unit commitment.

Settlement

In a financial-binding ahead market, participants would be settled on the ahead market schedule (transactions) at the ahead market clearing price for each of the products they trade in the ahead market.

The real-time market then becomes a balancing settlement such that only deviations away from the ahead schedule are settled at the real-time price. This means that for those participants that follow their ahead market schedule exactly, they will be settled at the ahead market price, whereas for those that do not participate in the ahead market, they will be settled at the real-time market price.

Where three-part bids are included for energy trading, the market could guarantee recovery of ahead market costs for those participants using three-part bids and corresponding commitment constraints by providing make-whole payments in case their ahead revenue does not recover their entire costs. However, it is not necessary for the design to include this feature. An alternative option is to leave ahead market participants to manage their cost recovery risk through their own bidding as per the current NEM design.

Forward contract market interaction

The ahead market design will need to consider how participants will manage forward market risk and any implications for the contract market. Under a voluntary ahead market design, the decision to trade contracts referencing the ahead market or real-time prices can be left to industry. However, if there is to be a considerable portion of forward contracting against the ahead market price then there is likely to be value in facilitating and coordinating transition arrangements that could include establishing new electricity futures contracts as well as new standardised products for OTC markets.

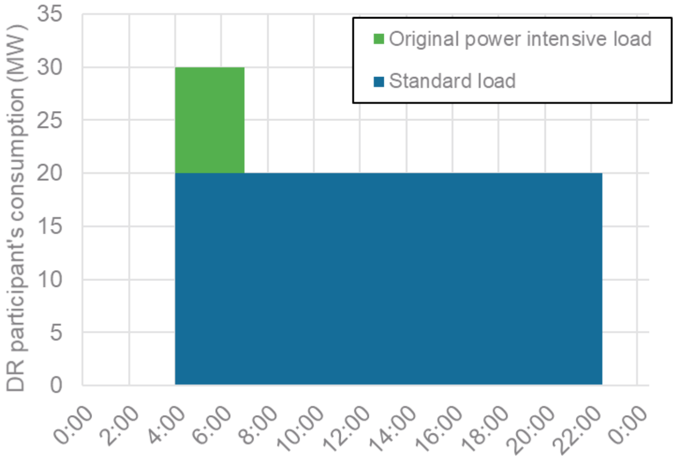
Correspondingly, if the CoGaTI reforms are adopted, it can be expected that the FTR should also be referenced to the ahead market price.

Finally, with the ahead market providing a platform to trade system services, it may also be that there is an ability to form forward contracts for system services referenced to ahead market prices.

Use case – demand response

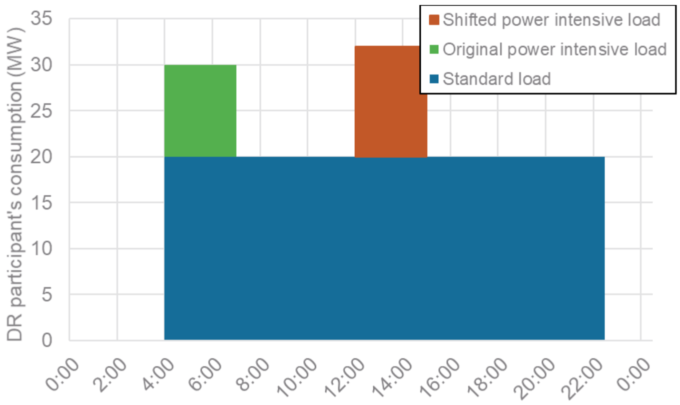
The following use case demonstrates how a large user can use an ahead market to schedule its demand response.

Consider a factory which has a flat load for the majority of the day (20MW from 4.00am to 10.00pm), with an additional power intensive load (additional 10MW) that it typically runs between 4.00am and 7.00am when prices are low.

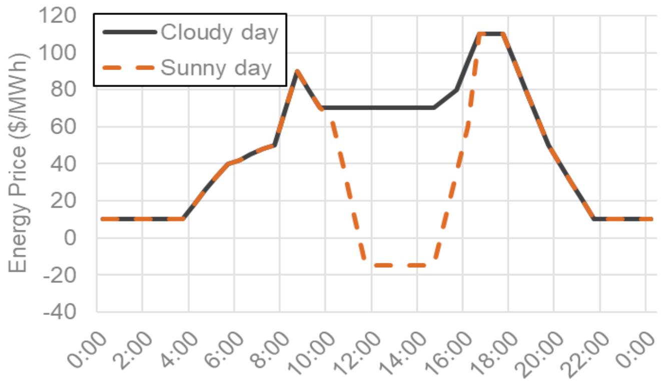


The factory can shift its power intensive load to the middle of the day, but to do so:

- 20% additional power is consumed by the process, such that it is now 12MW for the three hours that it runs (due to start-up and other inefficiencies later in the day, such as temperature difference).
- A decision needs to be made by 5.00pm the day before to arrange staff and other processes.
- Once a decision has been made to shift the load, it cannot shift again, and the process must be run.



Now, consider the difference in expected prices on typical cloudy days with limited solar, and on sunny days where the price drops in the middle of the day. On sunny days, the factory could shift its load and take advantage of the cheap energy, but on cloudy days it would pay more (assuming it is exposed to the wholesale price). There is also a greater risk of unexpected price spikes in the middle of the day (eg. due to unexpected cloud cover) compared to early in the morning.



The factory will be better off shifting its load if the mid-day price is lower than $20/MWh, otherwise it will incur additional cost overall by shifting load. With a real-time only market, the factory needs to make its decision by 5.00pm the day before. based on predicting the weather and/or relying on pre-dispatch in the day ahead timeframe. Even if the pre-dispatch indicates a price lower than $15/MWh for the afternoon, this is uncertain, and a lot can change in the lead-up to real time. For example, unexpected cloud cover could arrive the following day, resulting in prices greater than $20/MWh.

This decision process is risky and the factory may not have the necessary operational capabilities and access to market information to support this decision making. While the factory could contract with a third party who could organise the load shifting on its behalf, this only shifts the underlying risk of making the 5.00pm decision to the third party. The potential demand response will only take place is the third party is willing to accept this risk.

However, with a day-ahead market, the factory (or the third party on its behalf) can bid to run its intensive load in the middle-of-the-day at an expected low price. If the market takes the same view that prices are likely to be low in the middle of the day, that bid will be likely to clear and the factory will receive a schedule to run during the middle of the day. Assuming the bid clears in the ahead market, the factory locks in a financial return and allows the factory to organise its process the day before, in-time to provide the demand response.

There is also potential benefit for the system operation in securing this demand response. The shifting of load allows synchronous generators, who require a minimum load to run, to be online to provide system services.