Review of the Proposed Congestion Relief Market

as an alternate policy to the Congestion Management Mechanism.

Declan Heim

SOLA5050 Renewable Energy Policy

Assignment – Final Report

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Table of Contents

Table of Figures

Table of Tables

Abbreviations

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
CMM	Congestion Management Mechanism
CoGaTi	Coordination of Generation and Transmission Investment
CRM	Congestion Relief Market
ESB	Energy Security Board
ISP	Integrated System Plan
LHS	Left Hand Side (referring to constraints)
MLF	Marginal Loss Factor
MW	Mega-Watt
NEM	National Electricity Market
NEMDE	National Electricity Market Dispatch Engine
PPA	Power Purchase Agreement
PV	Photovoltaic System
REZ	Renewable Energy Zone
RHS	Right Hand Side (referring to constraints)
SF	Solar Farm
SRMC	Short Run Marginal Cost
VRE	Variable Renewable Energy

1: Introduction & Context

Congestion is not new and debates on the structure of the Australian National Electricity Market [NEM] have long endured under the previously failed CoGaTi reform (Axup *et al.*, 2021), yet the challenges of NEM operability are increasing. The changing generation mix is leading to more dispersed renewable generation further from load centres while increasing system variability (AEMO, 2020). As a result, more congestion is suggested in the future (FTI Consulting, 2021). Since the NEM prices regionally, there is currently no price on congestion or visibility of its impact on stakeholders. This report will investigate the recent policy move to address this issue and the existing market challenges faced.

1.1: Existing Market Challenges

The premise of this pillar of federal government policy reform as part of the Post-2025 Market Design specifically the Congestion Management Model [CMM], is to address inherent challenges of how congestion is treated with respect to operational timeframes (Energy Security Board, 2021b). The defined challenges for which the CMM seeks to address (Energy Security Board, 2021d) are:

- Disorderly bidding behaviour from constrained units.
  Commonly referred to as 'race to floor bidding', under a binding constraint units will compete to maximise their dispatched volume and hence revenue, by bidding as low as possible. This results in a market dispatch with a merit order that does not accurately reflect short-run marginal costs.
- Risk of underutilisation of interconnectors and counter-price flows.
  Generators located close to interconnectors may be dispatched into neighbouring regions should there be intra-regional constraints between the generator and its respective regional reference node. In this situation, the generator is paid its region price which may be significantly higher than the neighbouring region. Ultimately, there is unequitable remuneration in such circumstances.
- Lack of incentives for storage to participate proactively to alleviate congestion.
  Currently NEM market arrangements do not provide any incentive for storage to operate as a load and alleviate congestion when it is needed by the market.

1.2: Congestion Management Policy Objectives

It is therefore proposed (Energy Security Board, 2021e) that any policy reform seeking to address these market challenges should be evaluated by the policy objectives to:

A. Improve locational signals for generation investment, ideally in REZs where co-ordinated transmission projects are focused.

B. Better utilize existing transmission network to more efficiency dispatch energy, to overall lower costs passed to consumers.

C. Reward storage to locate in areas of congestion, e.g., REZs, and operate in a way that alleviates constraints to benefit the broader whole-of-system.

D. Reassure investor confidence that investment will not be undermined by inefficient future connections of new generators.

Of these objectives, B and C most closely align to the reform from an operational perspective, while the relevance of A and D extend to addressing the longer-term investment horizon.

1.3: Proposed Implementation Options

Congestion Management Model with REZ adaptions – as proposed by ESB

The policy in the form of the CMM with REZ adaptions has been put forward as the preferred implementation by the ESB, while stakeholders continue to provide feedback through a process of submissions (Australian Government, 2021). In this design, all scheduled and semi-scheduled participants must pay a congestion charge per MW every dispatch interval. This amount of which would reflect their contribution to the cost of congestion within a specific region. Following such, only some participants would be eligible to receive a congestion rebate to mitigate the impact of the cost incurred (Energy Security Board, 2021c). Herein is a convoluted and opaque process of reallocating benefits.

Note: Further mention of CMM in this report specifically refers to the CMM with REZ adaptions proposal.

Congestion Relief Market – as proposed by Edify Energy

This implementation of the managing congestion allows voluntary participation of semi-/scheduled participants in a transparent market, akin to the existing energy spot market. Participants would be able to reveal their preference for purchasing congestion relief by bidding in a relief market, and sellers likewise would reveal their preference for providing relief by offering to the market (Stiel, 2021). A transaction would only occur should a constraint be binding, from which relief providers would only be paid for the amount of relief physically realised by the participants buying this relief.

Other proposals

Further options are not evaluated here given the ESB has explicitly stated they would "not provide efficient price signals in operational timeframes" (Energy Security Board, 2021c), however for context they include:

- Locational Connection Fees, suggested by the ESB – charging new generators a fee at time of connection. A further model based on this has also been suggested (Shell Energy, 2022).
- Generator transmission use of system charge (G-TUOS), suggested by the ESB – an ongoing fee for generators with locational consideration based on network topology (Energy Security Board, 2021c).

1.4: Report Outline

All in all, there is merit in assessing the CMM, its shortfalls and hence why the alternative CRM proposal may be more appropriate. The subsequent sections of this report, commencing with Section 2, provides a critical review of the policy. Background of the stakeholders most likely affected by the policy change are conveyed in Section 3, which further leads into a data modelling and quantitative analysis presented in Section 4. Synthesizing the review herein, Section 5 presents an evaluation of policy effectiveness, efficiency, equity and feasibility, while Section 6 and 7 capture the recommendations of this report and conclusions respectively.

2: Critical Review of the Policy

2.1: Evaluation of the Congestion Management Mechanism

Despite its infancy, the CMM policy has received large criticisms through stakeholder submissions. The issues raised within can be categorically described as follows.

Diminishing of the free-market approach and competition

The CRM would restrict new participants outside of a defined REZ from receiving any congestion rebate (Energy Security Board, 2021c). Such a reliance on an artificially defined boundary does not accurately reflect how congestion occurs from a power systems perspective. This policy suggestion would impose un-hedge-able risk to investment outside a REZ, so much so, that financing would be too costly even were it efficient to build in a location with abundant network capacity (Reid, 2022; Rolfe, 2022; Skinner, 2022; Streets, 2022; Zuur, 2022).

Investors should bare the risk of congestion

Further to the free-market approach, the current NEM arrangements are an open-access scheme allowing investors to decide where to build generation while baring the associated risks. It is similarly suggested that congestion should be managed by investors and operators through appropriate modelling and contractual arrangements. Not all projects are likely to share the same appetite for risk either (Geiser, 2022; Zuur, 2022).

Some curtailment is optimal

It is further widely accepted by industry that some curtailment is considered optimal from a whole-of-system view, as suggested in the AEMO Integrated System Plan (AEMO, 2021a). It can be more economical to oversize a utility-PV project in order to maximize capacity factor behind a thermal constraint, than to upgrade the transmission network in the respective area (Irlam, 2022; Rolfe, 2022; Streets, 2022).

Grandfathering issues

Grandfathering refers to favouring existing incumbent participants but creates a barrier to entry for new participants in doing so. This is a topical discussion in broader context, yet there are strong views that the CMM would grandfather existing generation with eligibility to rebates while new entrants would face added risk without such rebate. Arguments supporting grandfathering (Reid, 2022; Skinner, 2022; Streets, 2022), and against grandfathering (Tesla, 2022; Zuur, 2022) are dually noted.

Disorderly Bidding Behaviour

The ESB has raised disorderly bidding as a particular issue here. However, the premise of managing increasing congestion is granted by a future NEM dominated by renewable energy participants. In such circumstances, "race-to-floor" bidding behind binding constraints is negligible since these participants have largely equivalent short-run marginal costs close to zero. The overall cost impact of one utility-PV dispatched in favour to another is insignificant (Geiser, 2022; Irlam, 2022; Priftakis, 2022; Rolfe, 2022; Zuur, 2022).

The CMM is isolated from major transmission planning, some further claiming the policy is redundant

Minimising congestion can be achieved through effective co-ordination of transmission networks. Hence a focus on network planning would assist in facilitating higher uptake of renewable energy, yet the proposal for a CMM or its alternatives, have nothing to do with delivering transmission or the process therein. As such the motive for this policy is seen as redundant (Geiser, 2022; Priftakis, 2022; Rolfe, 2022).

2.2: Evaluation of the alternative Congestion Relief Market

Given the CRM policy has not progressed to the extent of the CMM, this critical review relies on the basis of the proposal by Edify Energy (Stiel, 2021) and further stakeholder support as revealed through the CMM consultation process (Hawker, 2022; Tesla, 2022; Zuur, 2022). Justifications made on how the CRM may address the shortcoming of the CMM policy (Stiel, 2021) are summarised in Table 1.

Table 1 Comparison of CMM policy issues and CRM policy implementations.

Suggested Issue with CMM	Addressing these shortcomings through the CRM
The policy forces mandatory participation on semi-/scheduled participants.	The spot market implementation of the CRM encourages competition through voluntary participation. The most effective, cost-competitive technologies would be rewarded for providing congestion relief.
Forcing a charge but not rewarding a rebate for some participants does not help them manage congestion risk.	Participants are better able to manage congestion risk by opting in/out of the market as they see fit.
'Equal sharing' for congestion costs through the congestion charge is inefficient as not all generators are equally affected by congestion. Some may overpay, and others underpay, for congestion relief.	Participants would reveal their individual preference of willingness to buy/sell congestion relief, ensuring efficiency.
Disorderly bidding as the core need for the CMM neglects the significance of power system stability impacts to congestion.	CRM would facilitate both thermal and stability congestion, remunerating providers that assist with improving power system stability which are currently not incentivised for such.

Final remarks concern criticisms for the CRM implementation option through industry working groups facilitated by the ESB (Energy Security Board, 2022). A key concern is the feasibility of implementation and how the CRM could be computed alongside NEMDE. Abuse of market power or 'gaming' the market was also raised. A response to such, suggests the transparency of the CRM in line with the current NEM would allow the AER to monitor bidding behaviour.

3: Stakeholder Overview

Whilst the proposed CRM would affect all semi-/scheduled market participants in the NEM who are involved in a binding constraint, there are two participants who are most likely affected by the change: utility-PV and utility-BESS. As reviewed in literature (Irlam, 2022), utility-PV is most impacted given an increasing occurrence of curtailment, while BESS has the potential to provide congestion relief (Tesla, 2022).

3.1: Utility-PV participants

Utility-PV is expected grow nine-fold in NEM by 2050 (AEMO, 2021b) but currently some participants face significant curtailment, such as Manildra solar farm reporting 40% less generation (Mazengarb, 2021). The thermal congestion in such cases is typically due to the high correlation in which all utility-PV participants tend to generate simultaneously (Heim, 2022). Additionally, stability constraints can pose curtailment risk, a notable case being the West Murray Zone in NSW (Maisch, 2020).

The CRM policy provides an opportunity for utility-PV participants to manage curtailment risk by purchasing congestion relief. Irrespective of the location of the participant within a REZ or not, access to this relief market is dependent fundamentally on whether a constraint is binding.

Potential challenges facing utility-PV under the CRM policy include the possibility that Utility-PV purchases congestion relief at a price above what it is paid in the energy spot market. This basis risk can be mitigated if the policy imposes a price cap so that the CRM price does not exceed the energy spot price (Stiel, 2021).

Finally, existing analysis of the policy impact on utility-PV participants is demonstrated through 'Example 2' of the proposal (Stiel, 2021), in which the revenue of the utility-PV generator improved by 50%. Additionally, the participant in this case who provided the system stability support was remunerated under the CRM unlike existing market rules.

3.2: Utility-BESS participants

Utility-BESS is an emerging energy storage technology growing in the NEM given its role to support the renewable energy. It is predicted that BESS would comprise 60GW of firming capacity that is needed by 2050 (AEMO, 2021b). Currently, BESS are only remunerated for a limited number of services (Heim, 2021) despite having technical capabilities to provide system strength, virtual inertia or fast frequency response. All of which are considered, crucial services for the future grid (AEMO, 2021d).

The CRM provides the opportunity for BESS to gain additional revenue by alleviating congestion. This opportunity is not confined to thermal congestion, rather stability constraints could also be alleviated by BESS (Heim, 2021). Such an opportunity for additional revenue is therefore suggested to be a locational signal for investors to build storage where it is needed most (Stiel, 2021).

A key challenge for BESS is in deciding its operational strategy given other markets and revenue streams. Should the CRM be effective, the incentive for BESS to charge during specific intervals has to be significant enough to compensate how it otherwise might behave.

Existing analysis on the impact of the policy on BESS is again nascent due to the policy progression. From 'Example 1' of the policy proposal (Stiel, 2021) it is clear that the storage providing congestion relief is remunerated for doing so, compared to the status-quo in which despite choosing to provide congestion relief or not, there is no remuneration or incentive to encourage load operation.

4: Policy Impact on Stakeholders – Data Model

This section details the policy impact on the prior stakeholders through novel counter-factual analysis using an open-source data model of the NEM, 'nempy', as well as the visualisation tool Tableau©. Supplementary detail of the model, including source-code, is appended to the report.

4.1: Research Question

How would the proposed Edify Energy's Congestion Relief Market (CRM) affect the spot market profitability of Utility-PV generators in the NEM which are frequently involved in binding thermal constraints?

4.2: Case Study

The question is addressed through a defined case study. This case assesses historical data from the 15th of February 2021 in which considerable Utility-PV generation was curtailed in the Central-West Orana region of NSW, as reported by various sources (AEMO, 2021c; Simpson, 2021). A visual representation of this study is displayed in Figure 2 with corresponding DUID references in Table 1 overleaf.

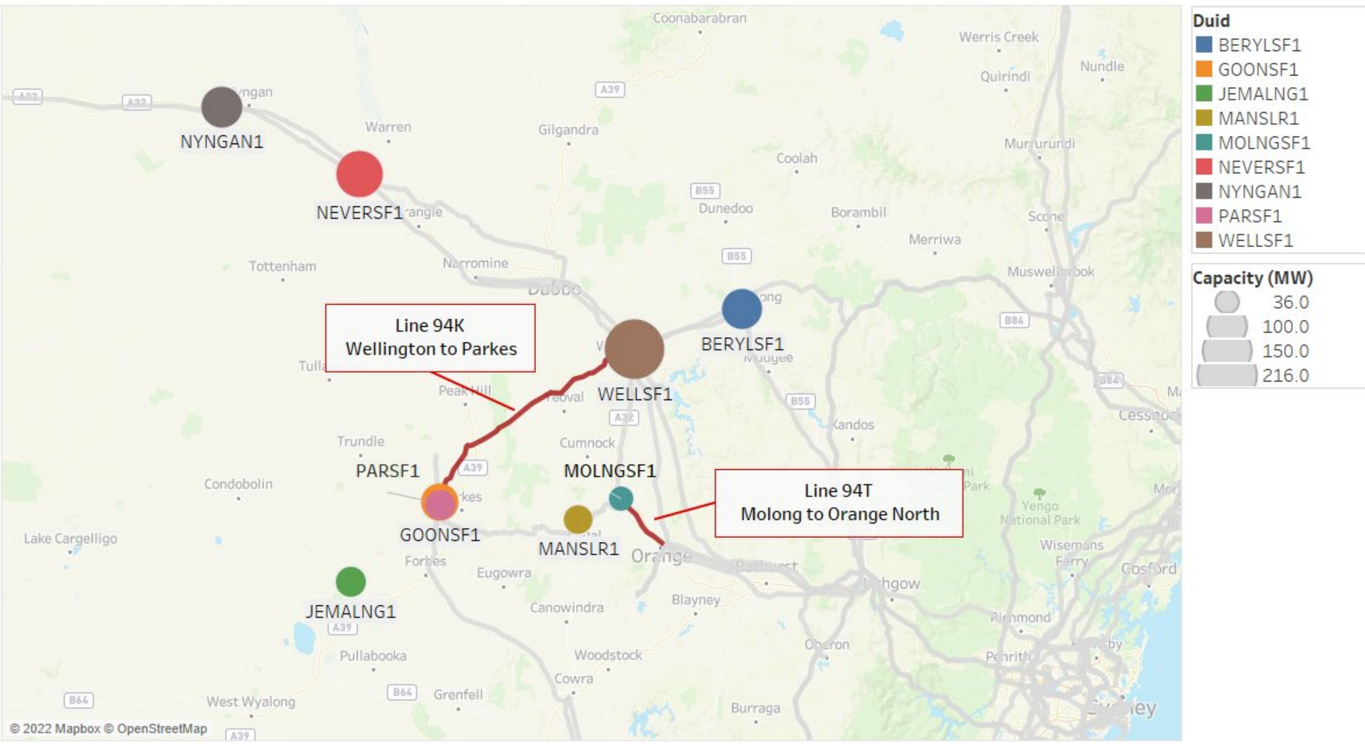

Figure 1 Locational representation of the case study showing transmission network (Orr and Allan, 2015) and relevant generation.

Specifically, the following parameters are defined in this case study:

- Simulation Period – historical dispatch interval data that is considered for simulation is confined to the 15th of February, 2021.
- Selected constraints – the considered thermal binding constraint equations for which the CRM is considered include:
    - Line 94T constraints: N>>N_NIL_94T, N>>N_NIL_94T_947.
    - Line 94K constraints: N>>N-PKWL_94K_1, N>>N-PKWL_94K_2, N>>N-PKWL_94K_3.

Note: 1. Line 94K constraints have not been modelled but included for context with specific extracts in the appendix. 2. A description of the constraint names is appended to the report as obtained from NEOmobile (Intelligent Energy Systems, 2022).

- Eligible Units – those units identifiable on the LHS of the selected constraints. These units are presented prior in Figure 2 and mapped to the respective constraints in the results section. Note that while Bodangora Wind Farm contributes to these constraints and is included in modelling, it has been omitted from the presented analysis given the focus here on utility-PV curtailment.

Table 2 DUID reference and registered capacity (AEMO, 2022a)**.**

DUID	Unit Name	Registered Capacity (MW)
BERYLSF1	Beryl Solar Farm	98.0
GOONSF1	Goonumbla Solar Farm	85.0
JEMALNG1	Jemalong Solar Project	55.0
MANSLR1	Manildra Solar Farm	50.0
MOLNGSF1	Molong Solar Farm	36.0
NEVERSF1	Nevertire Solar Farm	132.0
NYNGAN1	Nyngan Solar Plant	102.1
PARSF1	Parkes Solar Farm	55.0
WELLSF1	Wellington Solar Farm	216.0

4.3: Data

Input Data to the Model

This counter-factual data model requires extensive historical NEM data obtained from AEMO's Market Management System (MMS) which is published to NEMWEB (AEMO, 2022b). Various data sources obtained from MMS are configured as inputs to the 'nempy' simulator. Given these inputs are configured by the simulation package, details of each AEMO dataset are omitted, however these are noted in an example simulation of nempy (Gorman, 2022) as well as accessible via the appended source-code.

Output Data retrieved from the Model

By solving the economic dispatch model, nempy is able to provide market outcomes including prices, individual unit dispatch volumes, and information on binding constraints. Of the three key outcomes noted, market prices should remain unchanged before and after the CRM, unit dispatch volumes change in accordance with the CRM outcomes and finally non-zero marginal values[1] reflect where a specific constraint is bound.

[1] Marginal Values are variables within the NEM dispatch process per constraint that reflects the change in hourly dispatch cost should the RHS value of a constraint be increased or 'alleviated' by 1MW (O'Neil, 2020).

4.4: Method

High-level Overview

I. Using the case study parameters, an initial 'base case' energy dispatch simulation for a specific dispatch interval is performed in nempy. This yields the results of the historical market conditions.

   a. From the base case, it is verified that the 'selected constraints' are binding and units which are involved in the LHS of the constraint are identified. Only these units will be eligible to participate in a CRM associated with this constraint.

II. A second iteration of the dispatch simulation is performed with the selected constraints entirely removed, establishing a 'removed-constraint case'.

   a. From this case, the impact that the selected constraint has on each unit is identified by the difference in dispatch between the 'base case' and 'removed-constraint case'. This difference, typically an increase in dispatch volume in MWs, provides a maximum volume for congestion relief that can be bought by the respective unit for the associated CRM.

III. A simple dispatch model of the associated CRM is created for the 'selected constraints' and solved. The structure would follow the example on page 6 of Edify's submission (Stiel, 2021).

   a. Only eligible participants bids are modelled – step I.a. above.

   b. One congestion relief provider, a hypothetical utility-BESS, is created by adding this unit to the CRM.

   c. The offer/bid price that each participant submits to CRM is predefined hypothetically.

   d. A maximum cap is imposed on the amount of congestion relief bought, step II.a., and the price at which the congestion relief market can settle, being no greater than the energy price.

IV. Having solved the CRM associated with the selected constraint, generic constraints are written into the nempy model to define the CRM preference for dispatch so that the congestion relief providers and buyers are dispatched in accordance with the CRM outputs.

V. A third and final iteration of the energy dispatch simulation is performed given the considerations of step IV, and the addition of the hypothetical storage unit into the market.

VI. The results from the above procedure are collated from python, with the various output datasets visualized in Tableau. Repetitions of the above with variations to the CRM offer/bid prices can be considered as differing scenarios.

4.5: Limitations

The limitations of the presented data model and methodology include:

Limited information on the implementation of the policy given it is in the proposal stage.

Without explicit detailed design of the policy, a level of detail in the methodology must be assumed. For example, it is unclear whether a unit involved in two different binding constraints in a single dispatch interval would purchase congestion relief twice, should a new CRM be solved for each binding constraint or whether the units of neighbouring constraint nodes would be aggregated. The assumption in the case study assumes the aggregation of only two constraints for Line 94T.

Analysing constraints at an economic dispatch level is a level abstracted above transmission utilisation.

Without power-flow modelling, e.g., PSCAD or PSSE, the utilization of transmission lines cannot be determined accurately. Hence Objective B of the policy cannot truly be assessed, only the incentivises for storage and impact to PV profitability is judged as such.

The ability to model new storage is limited without knowing their behaviour in other markets.

A hypothetical storage unit is considered at the presumed connection point of Beryl SF. A true assessment of the policy impact on storage cannot be assessed without more exhaustive modelling of how that storage might have otherwise participated in the NEM energy and FCAS markets.

There is uncertainty of participant bidding behaviour in the CRM.

Only hypothetic bids can be modelled for participants in the CRM given the market does not yet exist and it is unknown what each participant's bid or offer may be. In this model, participant bids are assumed to be static, yet in practice it is more likely to be dynamic across time given changing circumstances in the NEM.

Determining the net profitability of participants is not clear.

The net profitability of participants cannot be determined given a lack of information on possible contracting arrangements outside the spot markets modelled. These contract mechanisms may be pre-existing or alternatively new contracts established around the CRM to hedge against additional exposure in this new market.

4.6: Results & Discussion

Establishing the Base Case

The initial procedure involves a base case reflective of historical constraints with no CRM implemented. The dispatch simulation is run for iterations; 1) with all historic networks constraints, 2) as per iteration 1 however with the selected constraints removed from the model. Table 2 below specifies which units are considered and their LHS coefficients which can be interpreted as a 'contribution factor' towards each constraint.

Table 3 DUID LHS Coefficients corresponding to each constraint.

	Unit									
Constraint	BERYLSF1	BODWF1	GOONSF1	JEMALNG1	MANSLR1	MOLNGSF1	NEVERSF1	NYNGAN1	PARSF1	WELLSF1
N>>N-NIL_94T	0.0842	0.1284	0.4734	0.4007	0.8727	1.0000	0.1517	0.1517	0.4734	0.1517
N>>N-NIL_94T_947	0.1355	0.2025	0.5049	0.4273	0.8803		0.2379	0.2379	0.5049	
N>>N-PKWL_94K_1	0.0851	0.1221	1.0000	1.0000	1.0000		0.1416	0.1416	1.0000	
N>>N-PKWL_94K_2		0.1007	0.6589	0.6589	0.9176	1.0000	0.1207	0.1207	0.6589	0.1207
N>>N-PKWL_94K_3	0.1135	0.1734	0.6589	0.6589	0.9176		0.2051	0.2051	0.6589	

The results of this dispatch are presented in Figure 3 where only the line 94T constraints have been considered and removed, namely, N>>N-NIL_94T and N>>N-NIL_94T_947. The specific participants most relieved by the removal of Line 94T constraints are Beryl SF, Parkes SF, Goonumbla SF.

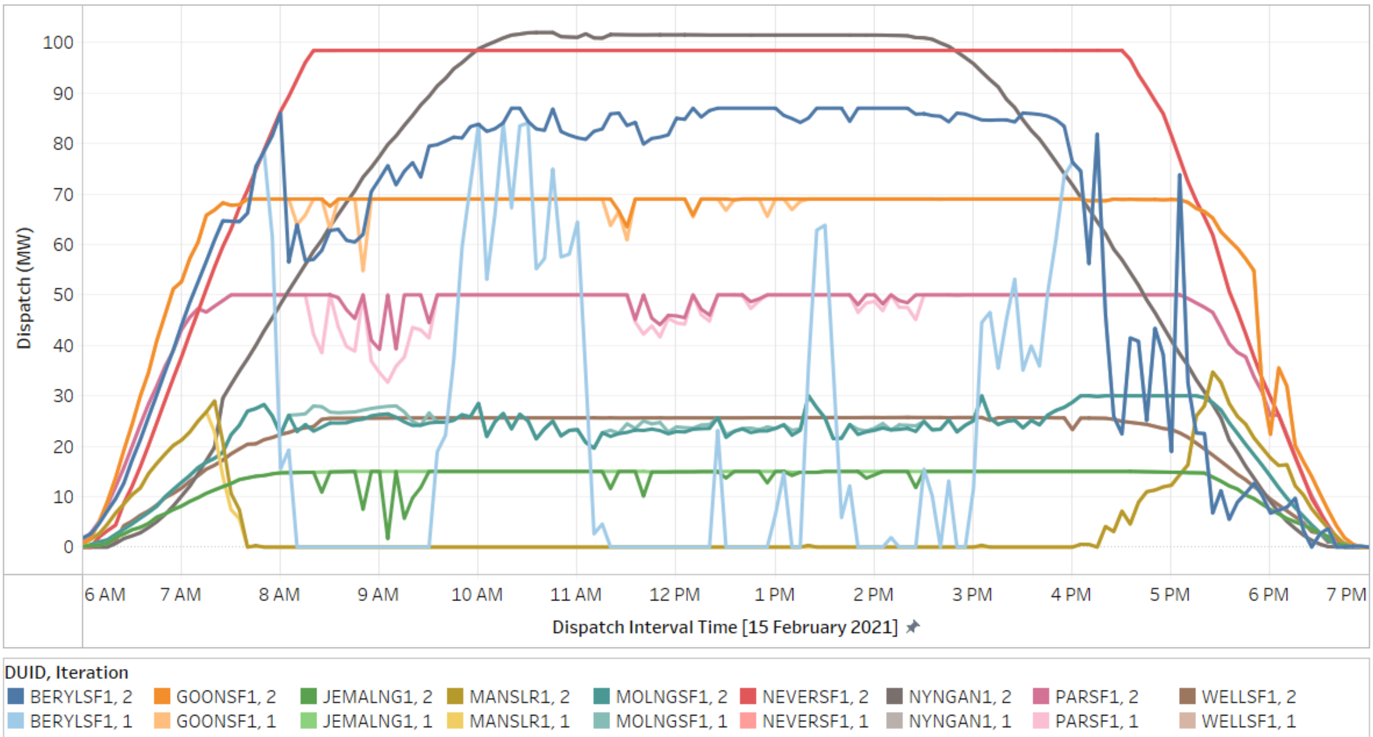

Figure 2 Dispatch simulation with (iteration 1) and without (iteration 2) selected 94T constraints.

As an aside, while fluctuation in generation is observed after 4pm this should not mistakenly be attributed to other constraints, rather the cause can be attributed to the variability of generation due intermittent weather. This behaviour is explained in the appendix.

CRM Model Inputs

The CRM is modelled in nempy as a separate market with three participants across two scenarios. Table 3 and Table 4 define how two solar farms bid to buy congestion relief from one storage unit offering to provide relief.

Table 4 CRM Model Bidding Input Assumptions – Scenario 1.

	DUID	Bid/Offer Price	Bid/Offer Volume
Supply Offers	STORAGE	50.0	50.0
Demand Bids	BERYLSF1	60.0	87.0 (Registered Capacity)
	MANSLR1	10.0	46.0 (Registered Capacity)

Table 5 CRM Model Bidding Input Assumptions – Scenario 2.

	DUID	Bid/Offer Price	Bid/Offer Volume
Supply Offers	STORAGE	10.0	50.0
Demand Bids	BERYLSF1	20.0	87.0 (Registered Capacity)
	MANSLR1	1.0	46.0 (Registered Capacity)

Importantly, further elements of the policy are that the congestion relief buyers should only be cleared for the amount of relief feasible (Stiel, 2021). Although the above bid volumes aim to relieve as much curtailment as possible, a subsequent process in the model adjusts these values every dispatch interval to reflect the extent of available congestion relief under the selected constraint. Most often than not, Manildra SF in the above tables has a volume reduced to zero, given its curtailment cannot be alleviated by this constraint, as evident in Figure 3. The second feature of the policy is to cap the CRM clearing price to the cleared NEM energy price to mitigate basis risk of the congestion relief buyer (Stiel, 2021). This is considered a sensitivity, demonstrated through Scenario 1.

Congestion Relief Model Dispatch Results

The results of the CRM market are presented in Figure 4 and Figure 5 respectively for the storage congestion relief provider and for the relief buyer being Beryl SF. Manildra is omitted from analysis given minimal participation at times outside of Beryl SF's curtailment alleviation.

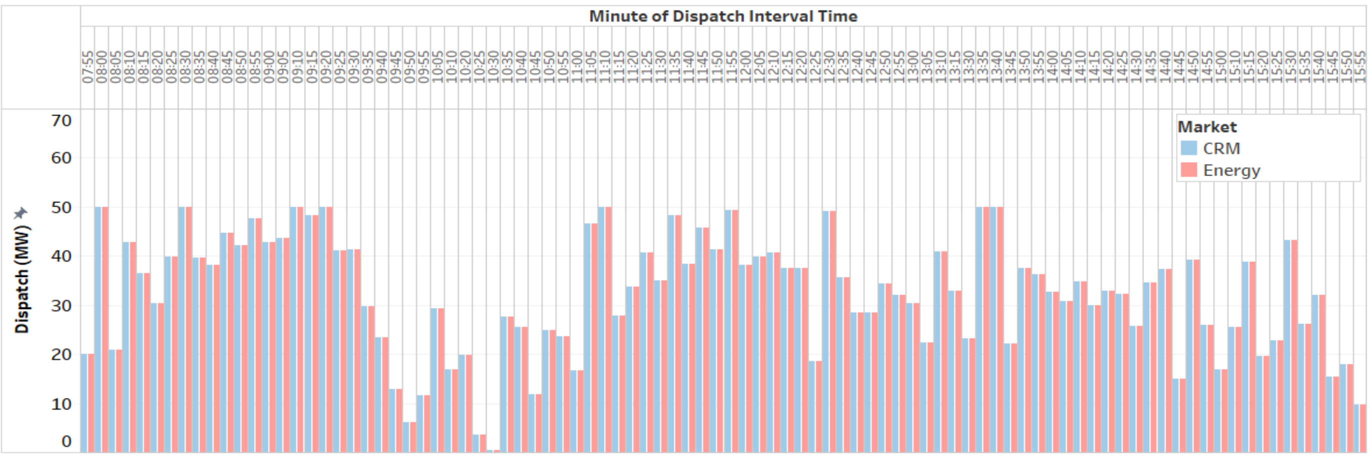

Figure 3 Storage unit dispatch (as a load) in CRM and Energy markets for applicable hours.

Figure 4 demonstrates that the storage has been dispatched as a load to the corresponding amount of congestion relief provided in the CRM. The modelled CRM is only in effect for intervals of Beryl SF being constrained down, here from 07:55 to 15:55 hours.

The perspective of congestion relief from Beryl SF is further depicted in Figure 5. The CRM dispatch for Beryl SF is compared against the dispatch difference, the earlier metric calculating the maximum possible alleviation under the selected constraint as per Figure 3. The main observation here is the limitation of congestion relief being provided to Beryl SF at a maximum of 50MWs due to the CRM offer from the storage unit. On six occasions, Beryl SF faces some curtailment even with the implemented CRM due to not being able to acquire enough relief.

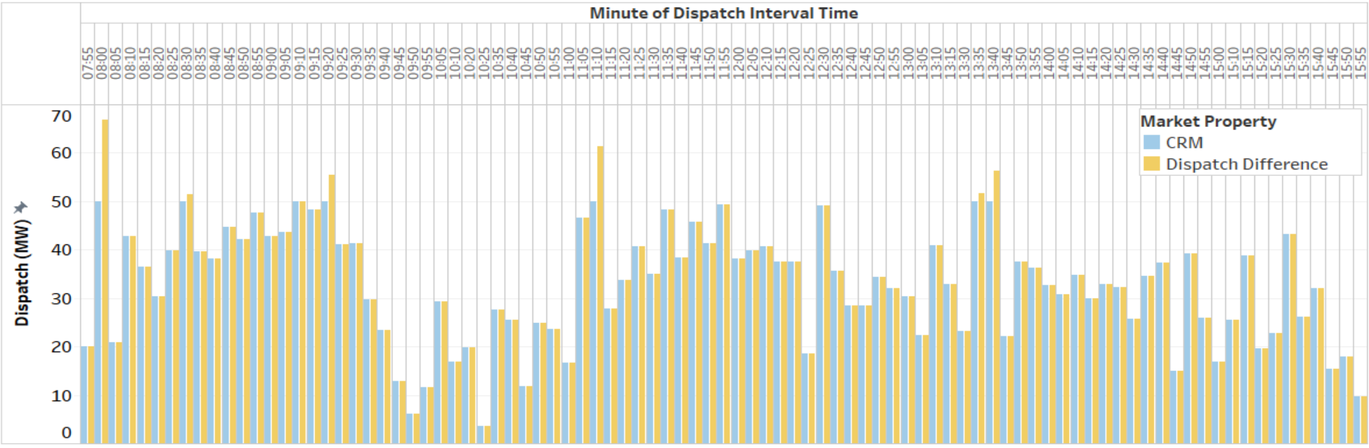

Figure 4 Beryl Solar Farm unit dispatch in CRM and practical amount of congestion relief available.

Energy Market Dispatch Results

Contextualizing the results of the CRM participants with all other participants involved in the constraint, the energy market dispatch of Scenario 1 is presented as Figure 6. Note the dispatch of other units is unchanged by the CRM implementation since they have not participated in such, with a negligible exception of Manildra SF between morning hours mentioned prior.

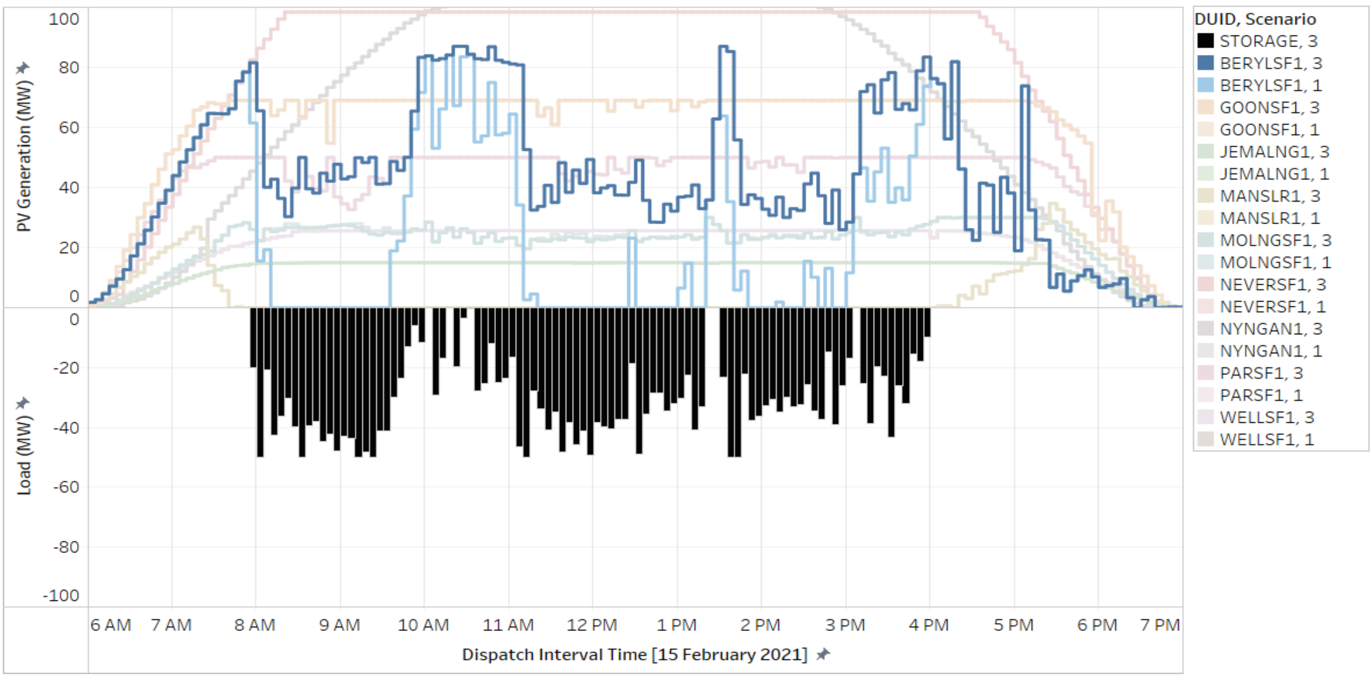

Figure 5 Energy Market Dispatch with CRM implemented, highlighting Beryl SF curtailment alleviation.

Congestion Relief Market + Energy Market Price Results

Ultimately, there is a financial impact of the CRM that is a core purpose of this policy. The prices settled for the modelled CRM under each scenario are presented in Figure 7. Dually this graph shows the energy spot price equal to the CRM price in Scenario 1. The energy price is unchanged for Scenario 2.

Unsurprisingly, should the bids fall below the energy price cap, the CRM clearing price is determined by where the bids and offers meet. Most often the demand for congestion relief is less than or equal to the maximum offer from the storage provider of 50MW, and hence the cleared price of Scenario 2 is $10/MWh as offered by the storage unit. However, on six occasions the demand for relief by Beryl SF exceeds the available supply and so the clearing price of the CRM becomes the bid price from Beryl SF of $20/MWh.

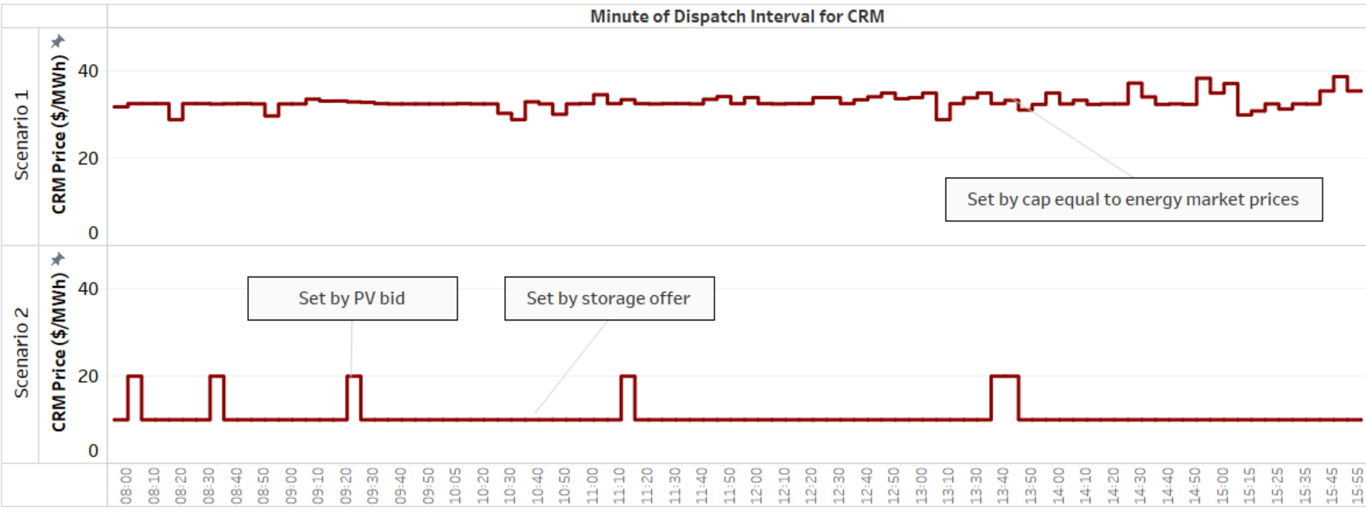

Figure 6 Comparison of CRM prices under each scenario.

Revenue Impact for Stakeholders – with CRM price cap

The modelled impact is presented in two subsequent figures overleaf, the calculations of which are appended to the report. Figure 8 presents the stakeholder revenue components of Scenario 1 from the energy spot market and CRM per dispatch interval. Similarly, Figure 9 conveys this for Scenario 2. In each figure, the first row represents the base case energy revenue only as a means of comparison, the second representing each revenue component for Beryl SF, and the third for the storage unit. A clear observation from Figure 8 is the equal and opposite revenue components of energy and congestion for all intervals of storage and similarly where Beryl SF is curtailed originally to zero. Hence the net zero revenue eventuating in these circumstances due to the CRM price equalling the energy price.

Overall, there is an increase in energy revenue of Beryl SF reflecting the increased energy dispatch due to the CRM. Both scenarios reflect the same dispatch volumes in iterations with and without the CRM, as such the energy revenue is unchanged between Figure 8 and Figure 9. However, the CRM price reduces and is hence reflected by smaller revenues for each participant for this component.

A consequence of this model is that a minimal number of intervals where the CRM outcomes cannot be resolved in nempy, result in missing data. The impact of this error is however considered negligible in the overall data model.

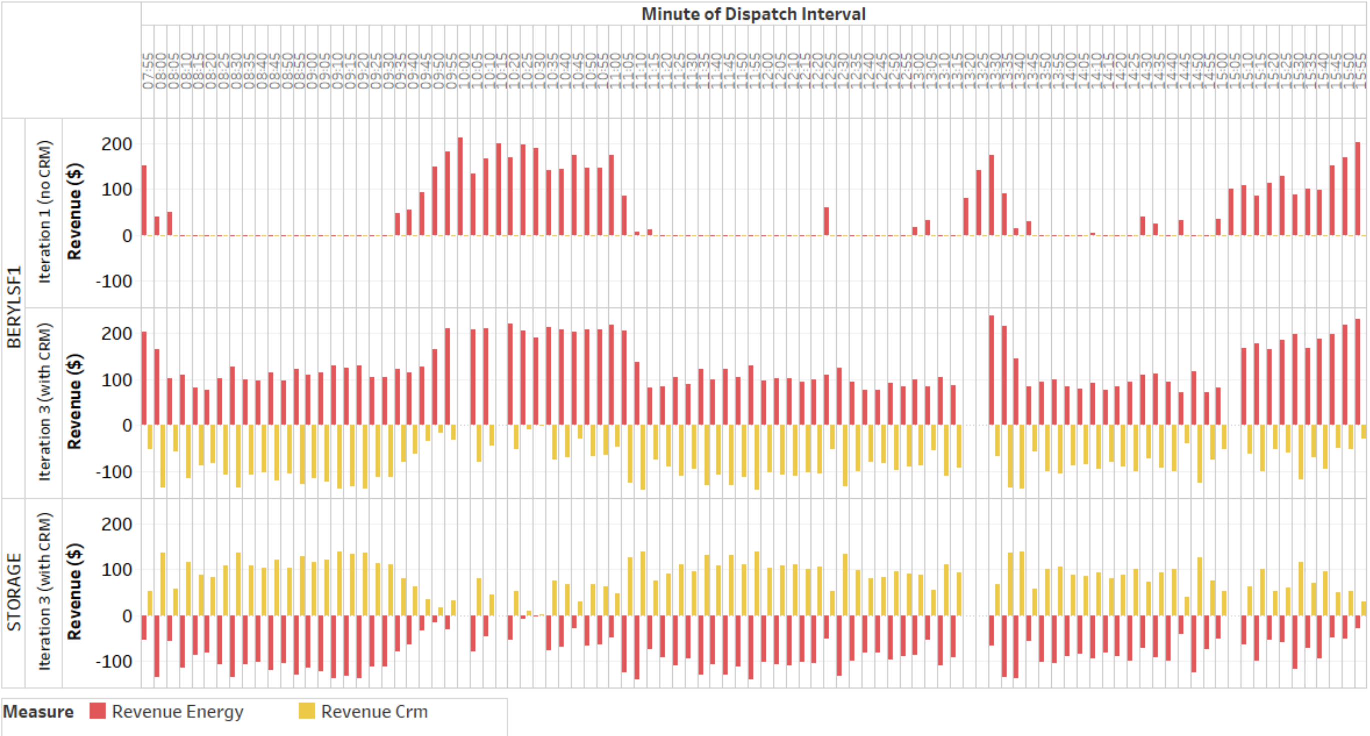

Figure 7 Stakeholder Revenues – Scenario 1 with CRM cap imposed.

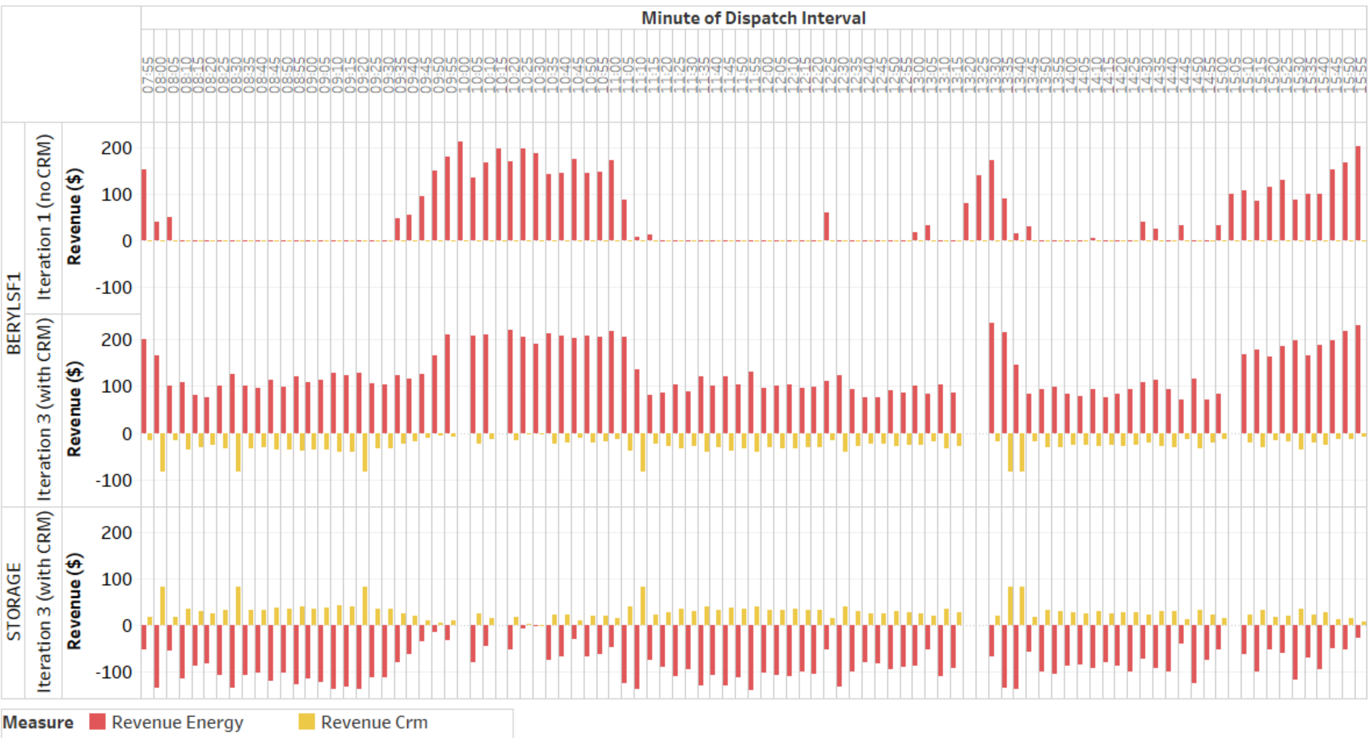

Figure 8 Stakeholder Revenues – Scenario 2 with offers/bids below the energy price.

Modelling Conclusions

This section explored a novel data model using nempy to address how the proposed CRM would affect the spot market profitability of Utility-PV participants specifically. The final consolidated results over the considered time horizons above are conveyed in Figure 10.

It can be concluded that the CRM although imposing a cost on utility-PV, may eventuate in a higher net revenue given the ability to dispatch more energy in the spot market, however this is not guaranteed. In the first scenario where the net revenue is originally $5.2k, participation in the CRM which clears equal to the energy price, degrades the net revenue to $3.9k. Hence Beryl SF suffers a substantial loss for this period. In contrast, the net revenue for Beryl SF improves in Scenario 2 to $9.4k given the same energy dispatch volume but minimised CRM cost. Such an outcome would be desired. From these results, it can be inferred that the preferred cost of congestion relief for Beryl SF is the cost at which it's net revenue would be unchanged with and without the CRM. This appears to lie between Scenario 1 and 2 CRM prices of $20 and $40. Hence ideally Beryl's CRM bid would be reflective of this break-even point, else it is favourable to be curtailed rather than pay excessively for CRM to one's own detriment.

For the storage participant, the CRM results in an overall net negative revenue unless the CRM price directly matches the energy price as per Scenario 1, in which case there is a net zero outcome. Alas, even with the CRM, this expenditure is reduced compared to the status-quo. In this context, it would be naïve to assume a BESS would operate as a load consistently throughout 08:00 to 16:00. The true impact to utility-BESS profitability therefore cannot be assessed within this scope.

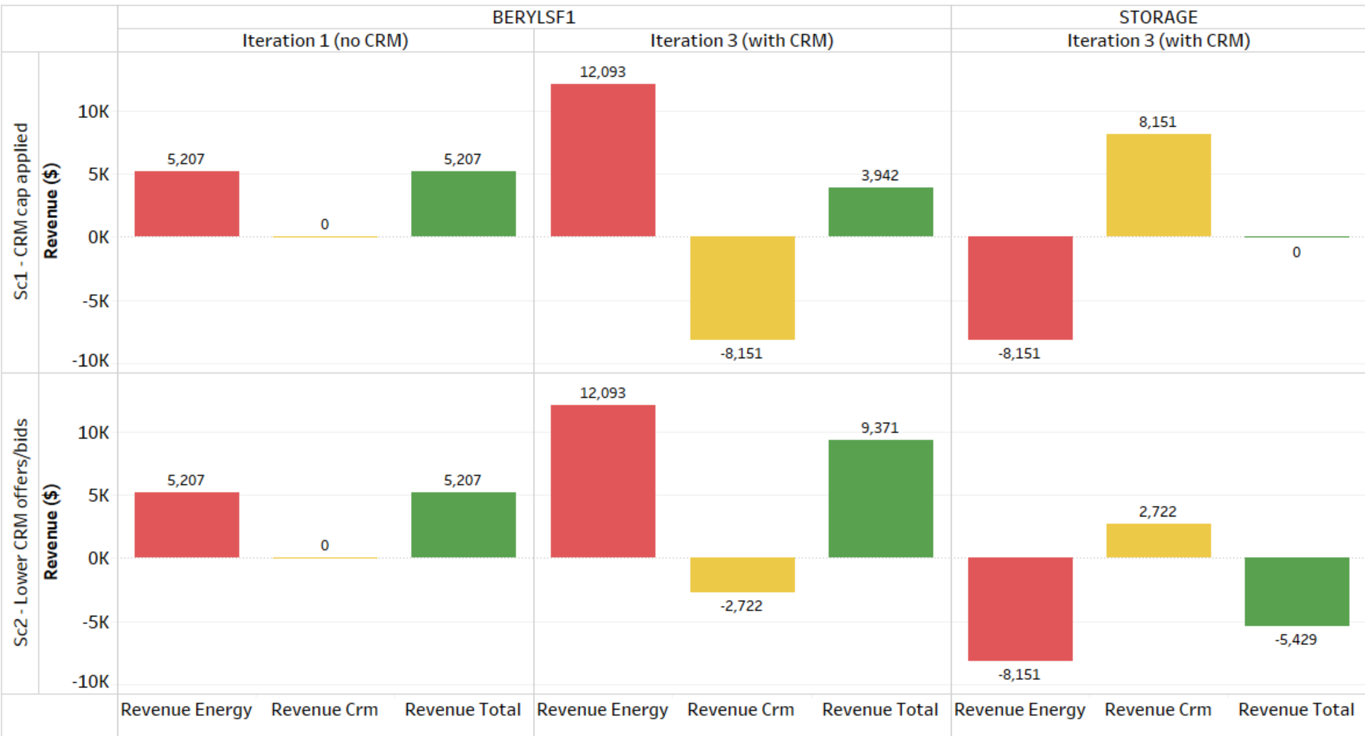

Figure 9 Final Revenue Outcomes per Scenario and Participant Analysed.

4.7: Significance

Although imperfect, this novel modelling approach goes to significant detail to highlight key complexities of the proposed policy that otherwise go un-noted. These issues raise key questions which can be succinctly summarized as:

Implementing a market per constraint, or a market per group of constraints?

This design implementation was noted in the limitations section. The former choice would result in insufficient competition in the CRM. A consideration for the latter approach would however be more complex in ensuring NEMDE dispatches the outcomes of the CRM while the remaining power system constraints are maintained.

Is there a significant incentive for storage?

As observed, the incentive for storage is effectively 'discounted' energy costs to charge the battery. It is not possible, ignoring negative price events, to make a net positive revenue without the CRM clearing above the energy price. Removing the cap does allow for storage to claim a premium however if the utility-PV is not willing to pay more, the CRM would not clear, ultimately retaining the status-quo.

All considered, how often would a CRM actually clear and influence NEM market outcomes?

This question is fundamental to the proposal of the CRM and the benefits that should address the policy objectives. In examples such as the one presented, it is difficult to confidently support the need for a CRM. Rather it raises more questions as to whether there is really a need for a relief market and how often it would deliver benefits to stakeholders.

4.8: Future Work

Further work on this model could analyse more rigorously the impact of the CRM on the specified participants through considerations of dynamic CRM bids and offers, further model scenarios, as well as capturing appropriately how BESS would decide to operate across the multiple markets to realistically capture the impact to this stakeholder.

5: Assessment of Policy Design

5.1: Effectiveness

The effectiveness of the policy is presented, evaluating how well the CRM achieves the defined policy objectives, as explored in Section 1.2.

Distinguishing from the CMM, the CRM would provide a clear indication of how congestion at specific nodes is valued. Should participants reflect a true marginal cost of preference for congestion relief, this design addresses a locational signal considering an operational timeframe in addressing Objective A of the policy. Alas, the same issues of market power that occur in the energy spot market could permeate the CRM given the like-for-like implementation.

Despite being unable to model transmission utilisation, the policy is likely to be effective in addressing Objective B, given the inherent reliance on constraints which reflect specific units and transmission lines locationally. The key incentive is for congestion relief providers to locate at nodes with higher contribution factors to constraints so as to have a larger impact in alleviating constraints and be remunerated for such (Stiel, 2021).

Objective C's effectiveness extends this prior point, further noting the ability to address both thermal and system security constraints.

Finally, investment risk is effectively mitigated, Objective D, by prompting the creation of financial hedge contracts around the underlying CRM (Stiel, 2021). By quantifying congestion and its value, derivative instruments would enable longer-term investor confidence and satisfy various risk tolerances.

5.2: Efficiency

Efficiency of policy design in this context, is a judgement considering the implementation costs of the market rule change weighed against the expected benefits that the policy would deliver. In lieu of detailed design, the implementation costs here are discussed through comparable NEM changes.

An evaluation of the proposed Congestion Management Model suggests an implementation cost of $10 – 20 million, in which the costs are attributed to a market settlement system outside of existing NEM mechanisms (Energy Security Board, 2021d). Comparably, other policy reforms suggested in the ESB Post-2025 reform package include Fast Frequency Response of $4-5 million, Operating Reserves of $8 – 15 million and Integration of Energy Storage Systems Rule Change of $20 – 30 million. Hence a valid assumption would presume CRM to be within this range, given the implementation focusses on adaptions of NEMDE like the above.

It is worth noting the suggested cost of network congestion to consumers in 2030 is in excess of $1 billion (FTI Consulting, 2021). This can be considered a cost of inaction for not implementing a congestion policy, however the premise of the modelling conducted is unreasonable. The assumption compares future NEM system costs with and without thermal and stability constraints, yet the basis of achieving a network without constraints is entirely impractical and unfounded in reality.

Nevertheless, the efficiency of the CRM policy is further dependent of whether the optional price cap is considered. If not, it is likely storage participants would abuse market power and drive the price of congestion relief considerably high. This would result in an inefficient outcome and force disproportionate costs onto utility-PV participants. Likewise, an outcome of the CRM not clearing and having no influence on the existing dispatch provides no benefit to the NEM as a whole, resulting in an overall net negative outcome when considering costs and benefits of the policy. All in all, there is considerable doubt as to whether the suggested CRM or otherwise would efficiently deliver the objectives of the policy.

5.3: Equity

The equitable nature of energy policy concerns the distribution of policy impacts and the ability for stakeholders to participate. The proposed CRM, with a price cap, is equitable given participants are able to purchase and others to provide congestion relief via a market settled when supply equates to demand.

The policy further allows for voluntary participation in CRM markets, unlike the CMM where a charge is imposed on all participants and a rebate withheld from some. A possible outcome of the CRM however may arise should one participant own both utility-PV and BESS assets, potentially 'gaming' the market to favour themselves. If so, some generators would continue to face congestion while others would benefit from increased revenues.

Bidding behaviour aside, given the CRM implementation modelled, the direct amount of congestion relief paid for would be received by the participant. The policy would not allow purchasing relief that cannot physically be delivered by NEMDE. Such attributes of the policy in this regard justify its equity.

5.4: Institutional Feasibility

In absence of detailed technical design, the institutional feasibility of the policy remains in doubt. The CRM is proposed to be implemented alongside the existing market implementation of NEMDE so as to co-optimise congestion markets with existing energy and FCAS markets. However as discussed prior in Section 2.2, should participants be required to submit a multitude of bids for congestion relief per constraint, this would add significant complexity to existing processes. Further the complexity for individual participants in formulating bids to submit to market is not insignificant. Given the uptake in auto-bidding processes (Global-Roam and Greenview Strategic Consulting, 2021) this may not be so unreasonable. In contrast to the CMM, implementing a transparent mechanism into existing NEM frameworks with information revealed to market is a certainly more desirable policy than a convoluted, opaque mechanism existing as a layer outside current NEM processes.

5.5: Policy interactions within the broader energy landscape

Crucially, the need and motives for the congestion management policies discussed are in-part being indirectly addressed through other policy reform and proposed mechanisms, lending to the notion of the CMM being somewhat redundant. The key market reform of transmission access rights from an investment perspective fundamentally addresses the co-ordination of generation and transmission build through the REZ framework (Energy Security Board, 2021a). This is the essence of Objective A of the policy. The further need for incentivising storage is arguably better addressed through reform for new markets such as system strength or inertia (Cass, 2021). Simultaneously by providing opportunities for hybridization of utility-PV and BESS projects through the 'Integration of Energy Storage Systems' rule change, this would provide another avenue for effectively managing curtailment (AEMC, 2021).

6: Recommendations

It is essential that any policy consideration for managing congestion in an operational timeframe considers an effective, efficient and equitable implementation that is also practically feasible.

As highlighted, there are many concerns for the CMM policy given the lack of transparency and equity of this policy design. It is not entirely clear that the policy would even address the objectives or the motive for its consideration as evaluated in Section 2.1. Contrastingly, while the CRM demonstrates an equitable and effective approach in addressing the objectives, the complexity regarding its implementation suggests at this stage that it may not be efficient or institutionally feasible. Further detailed design of the CRM is crucial to be able to address these points.

More broadly this report raises considerable questions as to whether congestion can efficiency be managed by any of the proposed policies noted, or whether there is in fact a need to do so. Importantly, the issues for locational signals for investment should be separated from operational dispatch considerations. It is clear through the interactions with other policy reform that the suggested need for a congestion management mechanism may be addressed in other ways. Finally, the more important issue here is progressing REZ policy reform regarding access rights, given the significant consequences of its inaction on the energy transition.

7: Conclusion

This report highlights a topical and complexing issue with no single compelling policy design that resolves the challenges raised. The review of the CRM as an alternative to the CMM addressed key shortfalls of the latter policy. As critically analysed in Section 2.1, the key issues of the CMM is that it lacks transparency and a free-market approach, fails to recognise the irrelevance of congestion to REZ boundaries, and in-part attempts to address an insignificant issue of disorderly bidding while having no relevance to transmission planning that ultimately resolves congestion. As an alternative, the CRM was not without concern either. The feasibility of implementing the CRM was questionable and hence further data modelling work was undertaken to highlight this overlooked detail.

Through a detailed model of the CRM, the impact to spot market profitability of a utility-PV generator was assessed. This model considered the significance of the CRM to both utility-PV and BESS participants involved in a binding thermal constraint. It revealed the complexities of congestion, with only one participant materially affected by the specific constraint for which the CRM was implemented. Subsequently the results of this model did demonstrate a benefit of congestion relief in providing utility-PV a higher net revenue by being able to dispatch more energy to the NEM, while BESS was able to purchase energy at a discounted rate than without the CRM. Yet, contextualised in the broader policy context, questions were raised questions on whether the incentive for storage was significant enough and how frequently the CRM might have an impact in the market.

All in all, the recommendations highlighted the key concerns of the assessment of policy design. Summarising these views, this report questions the need and motive for a congestion policy. There is sufficient evidence to suggest the benefits of the CRM for utility-PV or BESS are limited and that other currently discussed policies are perhaps better suited to address concerns raised in this initiative both from the perspective of the ESB and other stakeholders.

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Appendix

A. Modelling Source-code

The simulation files and descriptions are accessible online via the following GitHub page:

https://github.com/dec-heim/Constraints-Analysis/tree/main/SOLA5050-CRM

B. Supplementary Modelling Details

Constraint Name Descriptors

Table 6 Selected Constraints and Descriptions.

Constraint Equation	AEMO Description	Description
N>>N_NIL_94T	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	Thermal constraint to avoid overloading line 94T Molong to Orange North.
N>>N_NIL_94T_947	Out= Nil, avoid O/L Molong to Orange North (94T) on trip of Wellington to Orange North (947), Feedback	Alternate thermal constraint to avoid overloading line 94T Molong to Orange North should line 947 Wellington to Orange North trip.
N>>N-PKWL_94K_1	Out= Parkes to Wellington (94K), avoid O/L Molong to Orange North (94T) on trip of Forbes to Cowra (998) line, Feedback	Thermal constraint to avoid overloading line 94T should line 998 Forbes to Cowra trip while there is an outage on line 94K Parkes to Wellington.
N>>N-PKWL_94K_2	Out= Parkes to Wellington (94K), avoid O/L Molong to Orange North (94T) on trip of Nil, Feedback	Thermal constraint to avoid overloading line 94T while there is an outage on line 94K Parkes to Wellington.
N>>N-PKWL_94K_3	Out= Parkes to Wellington (94K), avoid O/L Molong to Orange North (94T) on trip of Wellington to Orange North (947), Feedback	Thermal constraint to avoid overloading line 94T should line 947 Wellington to Orange North trip while there is an outage on line 94K Parkes to Wellington.

Revenue Calculations for considered stakeholders.

The revenue impact for each stakeholder; Beryl SF and the storage unit, is calculated as defined in Equation 1 and Equation 2 respectively. These equations assume the load is not dispatched prior, however the solar farm is not necessarily curtailed to 0MW.

$$Net\ Revenue_{Storage} = [CRM - RRP]\left(\frac{\$}{MWh}\right) \times Load\ Dispatch(MW) \times \frac{1}{12}(h) \quad (1)$$

$$Net\ Revenue_{Solar\ Farm} = \left[RRP\left(\frac{\$}{MWh}\right) \times Total\ Dispatch(MW) \times \frac{1}{12}(h)\right] - \left[CRM\left(\frac{\$}{MWh}\right) \times Bought\ Relief(MW) \times \frac{1}{12}(h)\right] \quad (2)$$

Intermittent Generation Profiles.

It is important to note the intermittency of utility-PV generation profiles that may otherwise be mistaken as curtailment or constraining-down where simply the generation is affected by weather conditions. Figure 2 compares a dispatch simulation of the base case model, using nempy, for two historical dates with all network constraints removed and only imposing 'unconstrainted intermittent generation forecasts'.

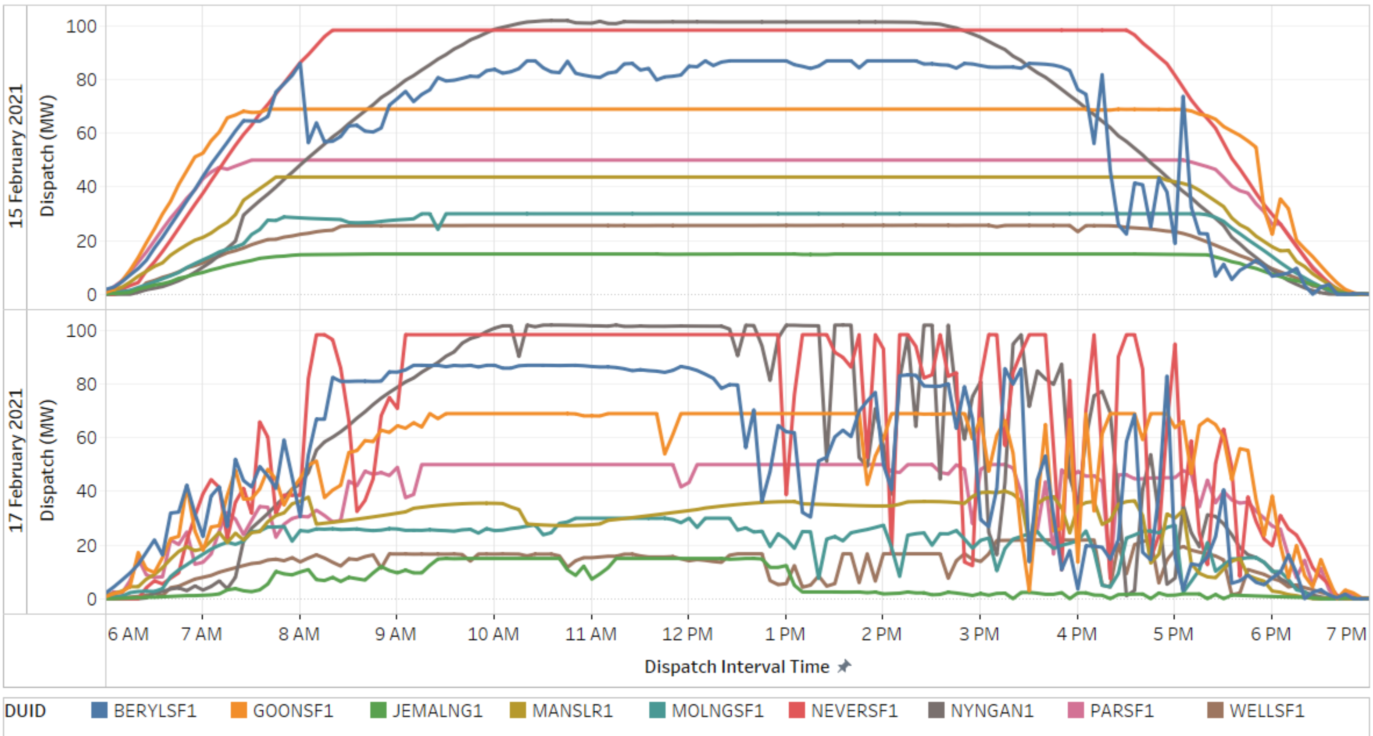

Figure 10 Intermittency of Utility-PV generation in the absence of network constraints.

Consideration of removing both Line 94T and 94K constraints.

Further relieving both line 94T and 94K constraints as presented in Figure 4, it is more-so clear that most SFs have curtailment relief, most noticeably Beryl as per the previous case and further Manildra SF largely affected by line 94K constraints in this case. Hence there is an opportunity to model a CRM considering these constraints and the impact that it may have on the considered units.

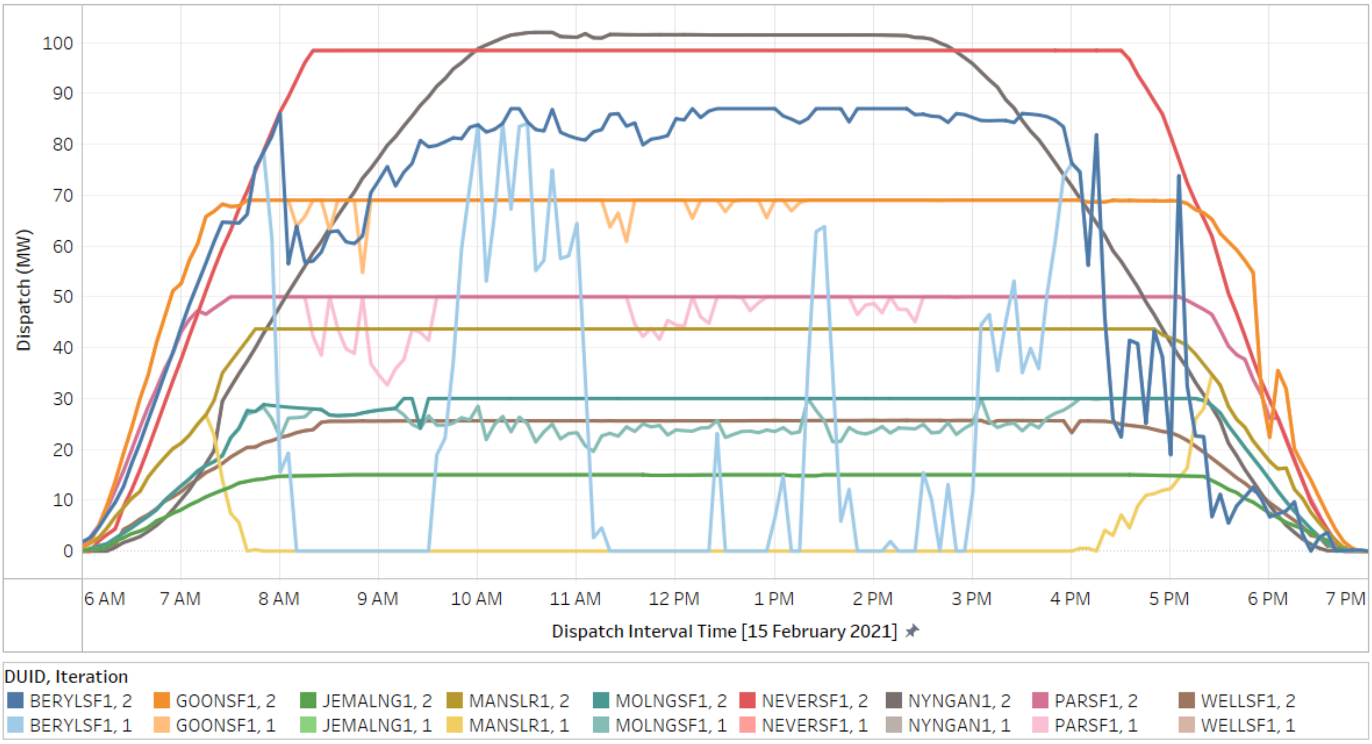

Figure 11 Dispatch simulation with (iteration 1) and without (iteration 2) selected 94T and 94K constraints.

{End Report}