DIgSILENT Pacific

Power system engineering and software

Australian Government
Australian Renewable Energy Agency

ARENA

Baringa
Brighter together

REZ development in the NEM

Technical challenges and potential solutions

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Introduction

- In Australia, the industry has identified the biggest risk for VRE integration is grid connection.

- For grid connection, the top 3 issues are:
  - Thermal congestion
  - System strength
  - Loss factor

- A good Renewable Energy Zone (REZ) should be able to manage these issues

- How?

Study scope

ARENA engaged Baringa and DIgSILENT to investigate the challenges for REZ development and potential technical, regulatory and commercial solutions

Phase one

Phase two

Phase three

Stakeholder consultation
- 16 bilateral meetings
- Governments, energy market bodies, investors, developers, technology providers

International case study review
- Challenges of, and approaches to, increasing renewable energy development

Case study modelling: NW-VIC and CW-NSW
- Near-term and long-term modelling of technical challenges and impact of potential solutions: network build, synchronous condensers, synchronous static series compensators, battery with grid-following inverters, battery and VRE with grid-forming inverters.

Regulatory and commercial options
- Qualitative analysis of potential options for near and longer-term REZ development, and supporting uptake of complementary technologies

Draft report

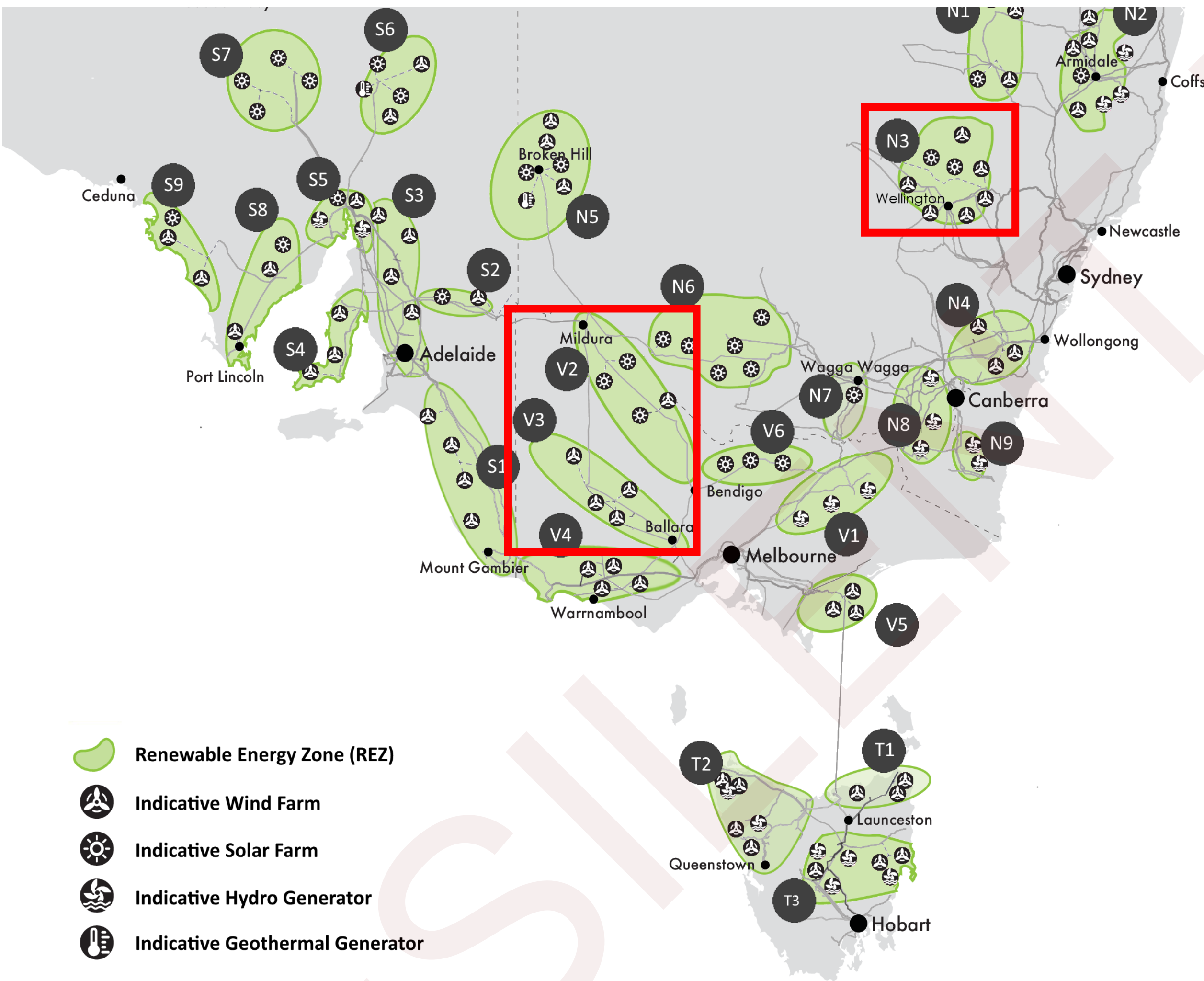
Stakeholder workshop

Final report

Project at a glance

- Two REZs:
  - Central West NSW and North West VIC
- Five technologies:
  - Syncon,
  - Battery with grid-following inverter
  - Battery with grid-forming inverter
  - VRE with grid-forming inverter
  - Synchronous Static Series Compensator
- Two constraints:
  - System strength
  - Thermal
- Two networks:
  - No change
  - ISP augmentation
- Three comparisons:
  - 5 technologies
  - Technology vs network augmentation
  - Coordinated vs uncoordinated approach

Renewable Energy Zones



- The two REZs demonstrate different technical challenges
- Both have significant resource potential, as identified in the ISP, that cannot be facilitated by the current network
- The NSW and VIC regions of the NEM are also facing coal plant retirements in the coming decade, and leveraging new generation potential will be important to replacing this capacity and maintaining reliability

Technical solutions investigated

Technology solution*	Description	System strength	Thermal capacity
Synchronous condenser	Essentially act as a motor that spins freely, without being connected generation or load. It either absorbs or generates reactive power to adjust to regulate the voltage in the grid.	Improve	Neutral
Battery with grid-following inverter	Utility-scale battery connected to the grid with an inverter that ensures the output voltage follows that in the local grid (rather than a fixed output voltage).	Reduce	Improve
Battery with grid-forming inverter	Utility-scale battery connected to the grid with an inverter that can set the voltage in the local grid (rather than a fixed output voltage).	Neutral / Improve (Depending on technology suppliers)	Improve
VRE with grid-forming inverter	VRE connected to the grid with an inverter that can set the voltage in the local grid (rather than a fixed output voltage).	Improve (Technology under development)	Neutral
Synchronous Static Series Compensator	Often considered a 'smart wire' technology. An SSSC is a technology (transformer and inverter) that can inject voltage into a transmission line to manage voltage or alter the power flow.	Improve (Existing SSSC may have a limitation during fault; technology under development)	Improve (Depending on network topology)

NW-VIC network build	Based on ISP 2018 and Western VIC RIT-T – assumes both the Western Victorian RIT-T projects and longer-term augmentation identified by ISP are built
CW-NSW network build	Based on ISP 2018 and discussion with TransGrid - assumes new 500kV circuits are built to Liverpool Ranges in 5-10 years

Modelling scenarios overview [1]

- DIgSILENT and Baringa models explore the technical hosting capacity of the REZ, how much developers could be expected to build commercially in the REZ, and the associated costs and benefits.
- **'Do nothing' scenario**:
  - This assumes that all existing and committed projects in each REZ (and across the NEM) are operational, with the current network
  - It then explores the current technical challenges (e.g. curtailment risk and poor system strength) and the potential future headroom if there were to be no additional network or non-network intervention
- **Uncoordinated technology implementation** assumes that when a technology solution is needed, triggered by connecting generation, it will be implemented at the site of the connecting generation. This is a simplified representation of the 'do no harm' approach.
- **Coordinated technology implementation** assumes that when a technology solution is needed, it is implemented at a network location and of a scale that is efficient for the REZ as a whole. (connection groups)

Modelling scenarios overview [2]

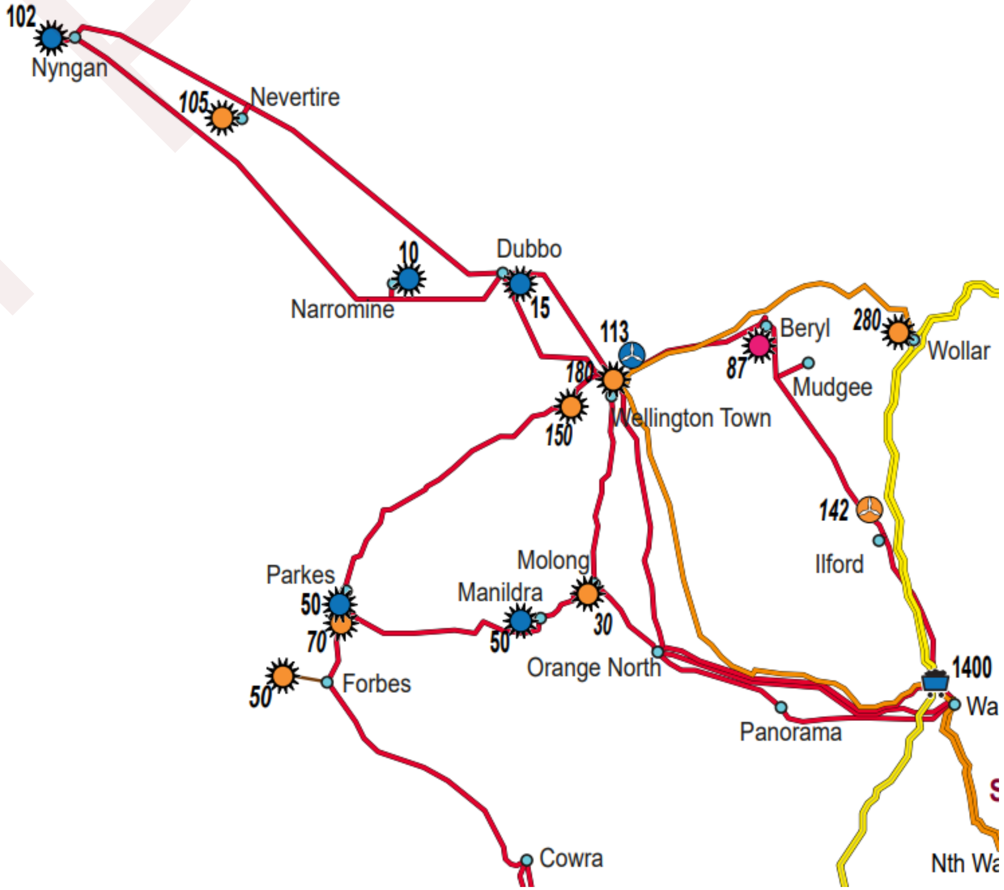
Scenario (C: coordinated implementation, U: uncoordinated implementation)	**Technology deployed**
Do nothing	Nil network or technology development in REZ
C1/U1	Synchronous condenser
C2/U2	Grid-following battery
C3/U3	Grid-forming battery
C3B/U3B	Grid-forming battery with higher fault contribution
C4/U4	Grid-forming VRE
C5/U5	Synchronous Static Series Compensator
ISP	ISP network build
Hybrid	ISP network build and optimal technology solution

Hosting capacity study

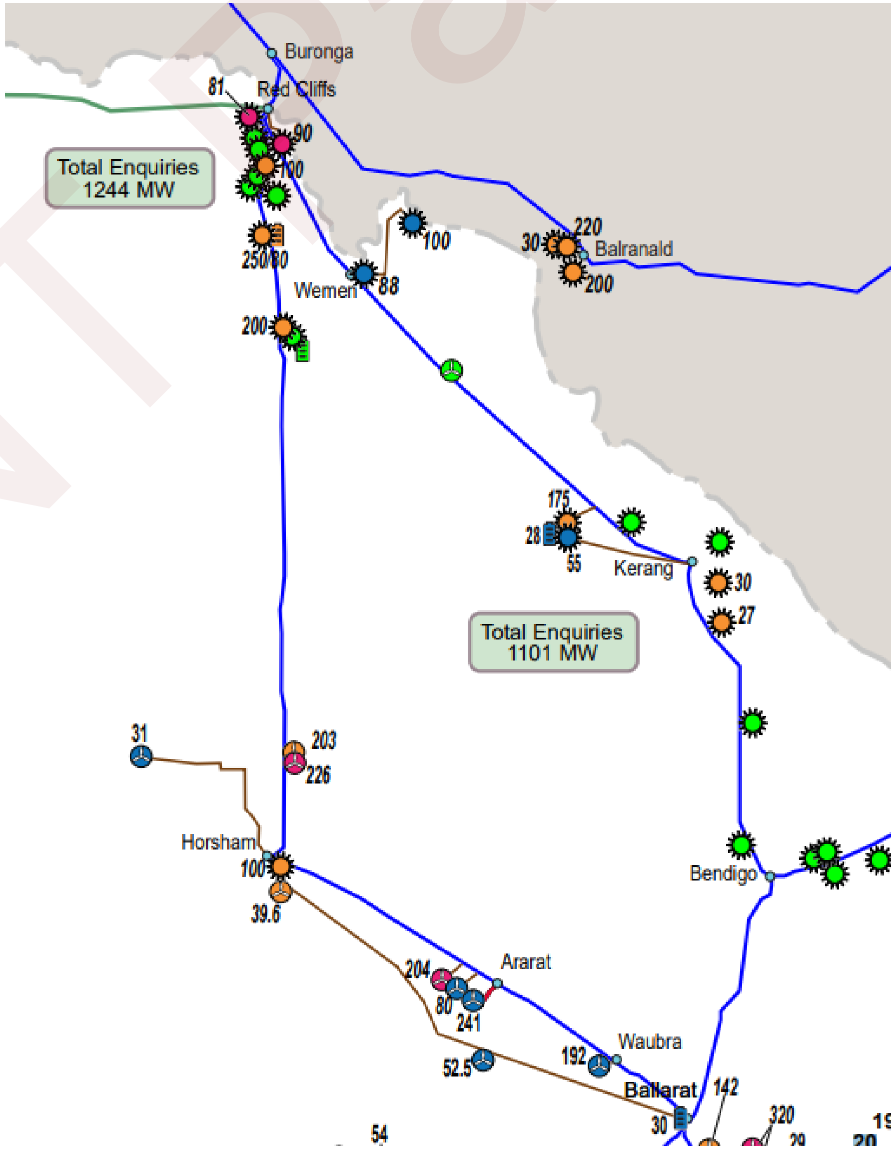
- The hosting capacity of the two REZs are based on consideration of two key factors:
  - System strength
  - Thermal constraint
- System strength assessment is based on the steady state methodology provided in AEMO's system strength impact assessment guidelines, which assume the minimum SCR at the POC to be 3
- New VRE entries are based on AEMO's generator information page and locations are assigned to the nearest existing substations for modelling simplicity
- Actual operational limit will be dependent on:
  - Generation dispatch, e.g. higher SCR can be available at night time when solar farms are not in service
  - System conditions like planned outages
  - Other special protection schemes

Results

REZ – CW NSW


102
Nyngan
105
Nevertire
10
Narromine
Dubbo
15
113
180
150
Wellington Town
Beryl
87
Mudgee
280
Wollar
142
Ilford
Parkes
50
70
Molong
Manildra
50
30
Orange North
50
Forbes
1400
Panorama
Cowra

REZ – NW-VIC



Buronga
Red Cliffs
81
90
100
Total Enquiries
1244 MW
250/80
100
88
Wemen
30
220
Balranald
200
200
175
28
55
Kerang
30
27
Total Enquiries
1101 MW
31
203
226
Horsham
100
39.6
Bendigo
Ararat
204
80
241
Waubra
192
52.5
Ballarat
142
30
320
54

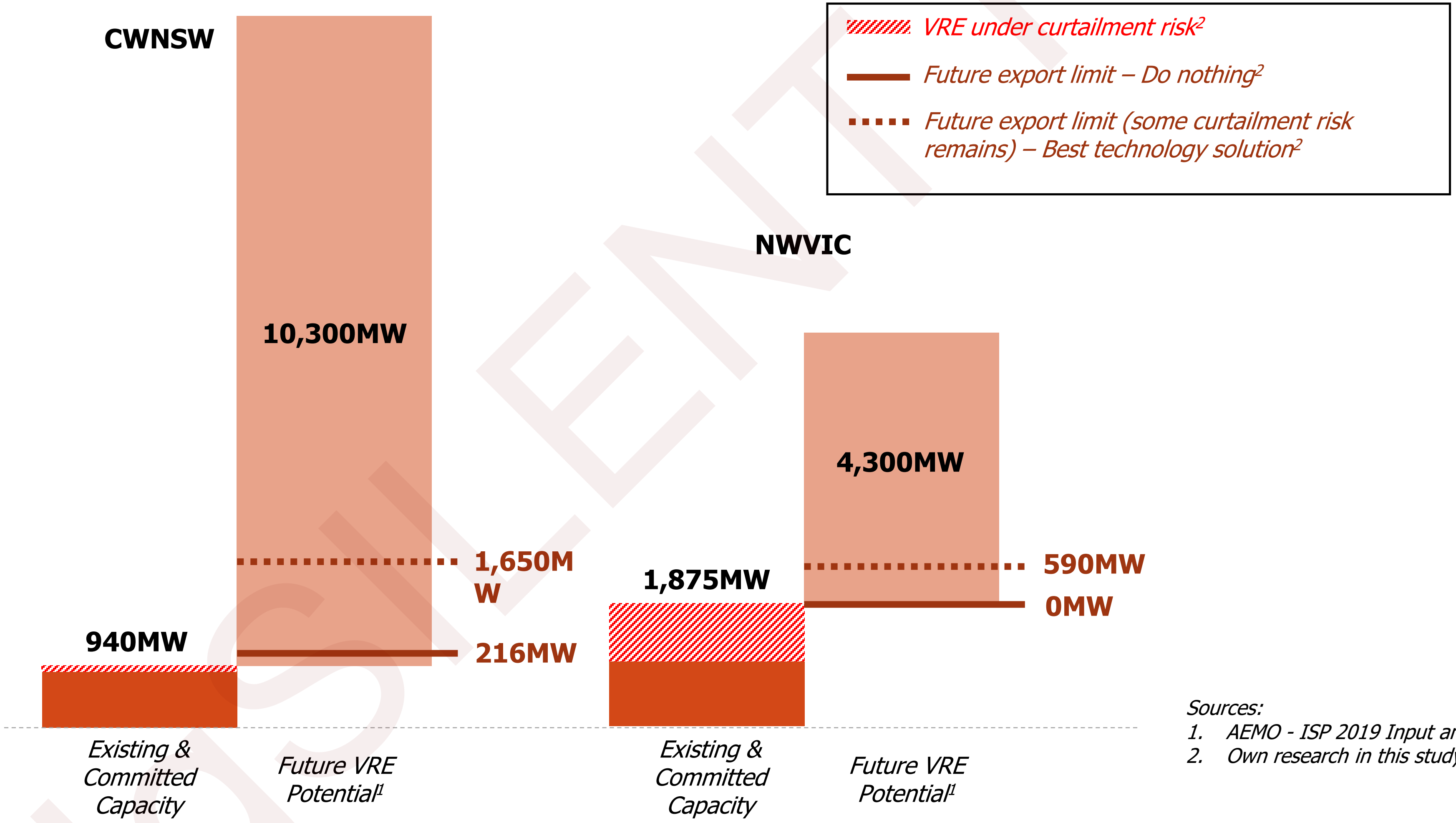
Key findings

1. Summary of resource potential and network constraint
2. Different technologies
3. Coordination vs. un-coordination
4. NW-VIC vs. CW-NSW

Challenge of developing REZs

These two REZs have recently seen active VRE development with available network capacity being rapidly exhausted. This is leading to increased risk of curtailments and hindering access to the significant remaining potential.

Resource potential and network constraint



Sources:
1. *AEMO - ISP 2019 Input and Assumptions Workbook*
2. *Own research in this study based on current network*

Comparison of different technologies (CW-NSW)

Synchronous condenser is the most cost-effective to facilitate new capacity in CW-NSW, with SSSC and batteries with grid-following inverters nearing cost competitiveness

Comparison of all coordinated technology solutions and network solutions

Scenario	Technology	Technology size and deployment location	Total VRE export limit change (MW)	Technology cost[1] ($ million)	Cost for additional export limit ($/kW)
C1	Synchronous condenser	- 100 MVA at Wellington 132 kV			
C2	Grid following BESS	- 55 MW at Molong 132 kV - 35 MW at Ilford 132 kV			
C3	Grid forming BESS	- 70 MW at Molong 132 kV - 35 MW at Ilford 132 kV			
C3B	Grid forming BESS with fault contribution of 200% nameplate MVA	- 70 MW at Molong 132 kV - 35 MW at Ilford 132 kV			
C4	Grid forming VRE	- 320 MW at Orange 132 kV - 1000 MW at Wollar 330 kV - 340 MW at Wellington 330 kV			
C5	SSSC	- 100% impedance increase for Molong – Orange line - 50% impedance increase for Ilford – Mt Piper line - 20% impedance decrease for Wellington – Mt Piper line			
ISP	ISP network build	- 2 x single circuit 500 kV from Wollar to Liverpool Range			
Hybrid	ISP + SSSC	- ISP: Same as in Scenario <ISP> - SSSC: Same as in Scenario <C5>			

Summary of findings

- As with NW-VIC, synch-cons in CW-NSW are found to be relatively cost competitive on a $/kW unlocked basis
- However, both grid-following and SSSC are found to be close to cost-competitive for delivery of a similar increase in headroom
- Compared to other technologies, batteries can secure additional revenues by offering commercial services including arbitrage, cap contract and FCAS, so the costs of batteries offering grid support are calculated as the residual costs after deduction of those revenues
- The ISP scenario comes out as very cost competitive, given the relatively modest upgrades required to unlock significant new headroom
- The combination of a near-term technology solution (unlocking ~1GW) and the longer-term ISP network upgrade (unlocking ~3GW) offers a compelling option at a competitive cost

Note:
1. Technology costs are calculated based on projection for financial year 2020

Comparison of different technologies (NW-VIC)

Cost-effectiveness of synchronous condenser in NW-VIC is unmatched by all other technologies in the near-term given the critical issues of system security in this REZ

Comparison of all coordinated technology solutions and network solutions

Scenario	Technology	Technology size and deployment location	Total VRE export limit change (MW)	Technology cost[1] ($ million)	Cost for additional export limit ($/kW)
C1	Synchronous condenser	- 22 MVA at Bulgana 220 kV			
C2	Grid following BESS	As grid following BESS reduces system strength, therefore it is not possible to deploy this technology in the NW VIC area with poor system strength			
C3	Grid forming BESS	- 300 MW at Murra Warra 220 kV - 310 MW at Bulgana 220 kV			
C3B	Grid forming BESS with fault contribution of 200% nameplate MVA	- 300 MW at Murra Warra 220 kV - 310 MW at Bulgana 220 kV			
C4	Grid forming VRE	- 590 MW at Ballarat 220 kV			
C5	SSSC	- 40% impedance decrease for Red Cliffs–Wemen line			
ISP	ISP network build	- Western VIC RIT-T project - Snowylink South[2] - 1x220 kV new circuit between Red Cliffs and Buronga, and one additional 330/220 kV new transformer at Buronga - 2x220 kV circuits Red Cliffs-Wemen-Kerang (replace existing line) - 1x220 kV new circuit Ararat-Horsham-Murra Warra			
Hybrid	ISP + Grid forming BESS	- ISP: Same as in Scenario <ISP> - 200 MW grid forming BESS at Murra Warra 220kV			

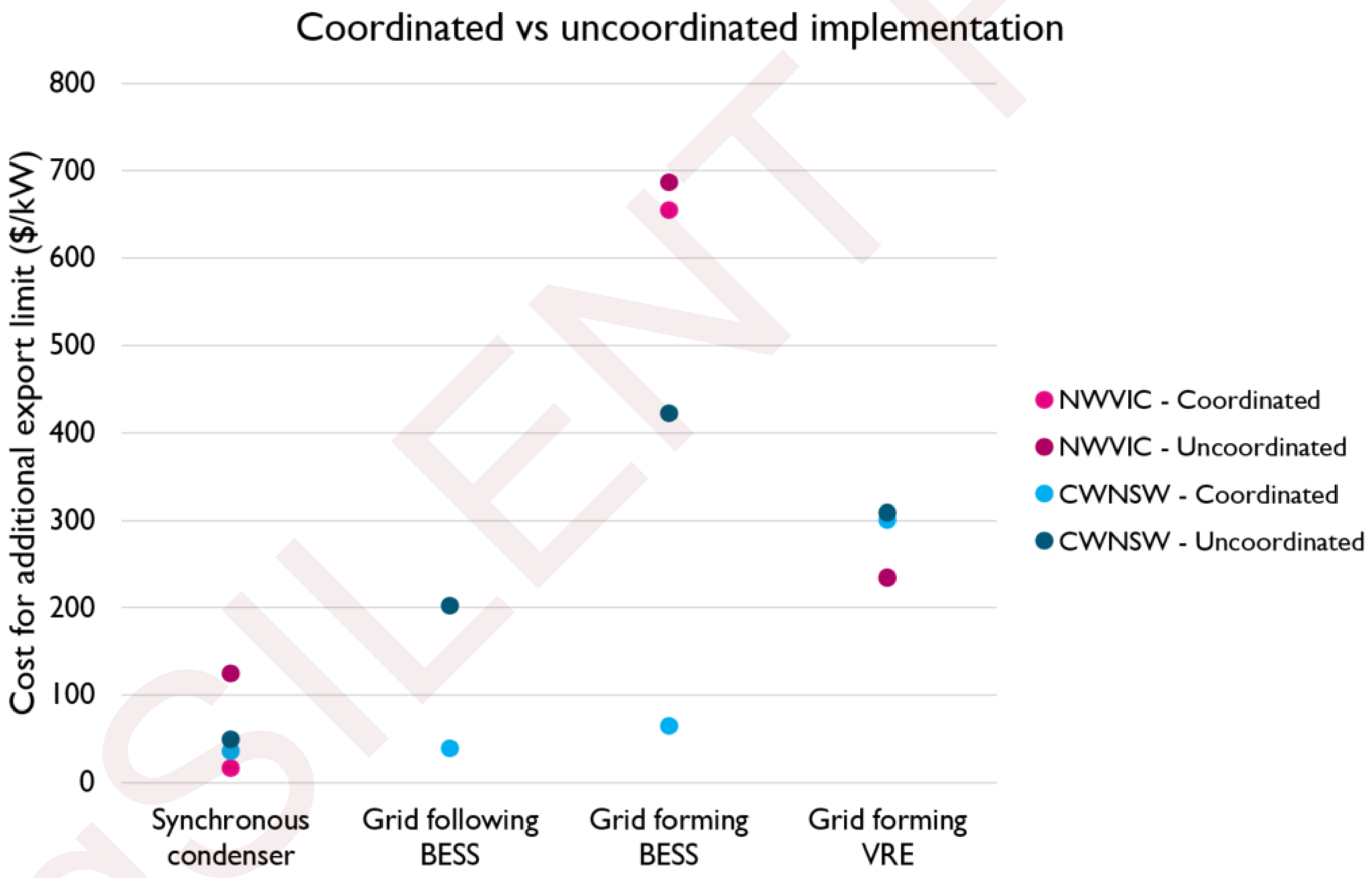
Summary of findings

- Since system strength constraint is the main issue for NW-VIC currently, synchronous condenser appears the be the pre-requisite in the near-term, and comfortably the most cost-effective option
- However, the synch-cons do not resolve current thermal constraints (curtailment risk), and so there could be a case for a grid-following battery alongside a synch-con
- As in CW-NSW, residual costs for batteries with grid-forming inverters are used in the analysis, but given the scale of deployment required (over 600 MW), they do not appear economic as a single solution for both system strength and thermal constraints
- SSSC is not found to be applicable in this REZ due to the network topology
- Given the state of the network, the ISP network build option appears like the only option for unlocking meaningful additional volumes

Note:
1. *Technology costs are calculated based on projection for financial year 2020*
2. *Cost for Snowylink South is not accounted in this study since it is an interconnector project that aims at a wider range of benefits instead of this REZ only*

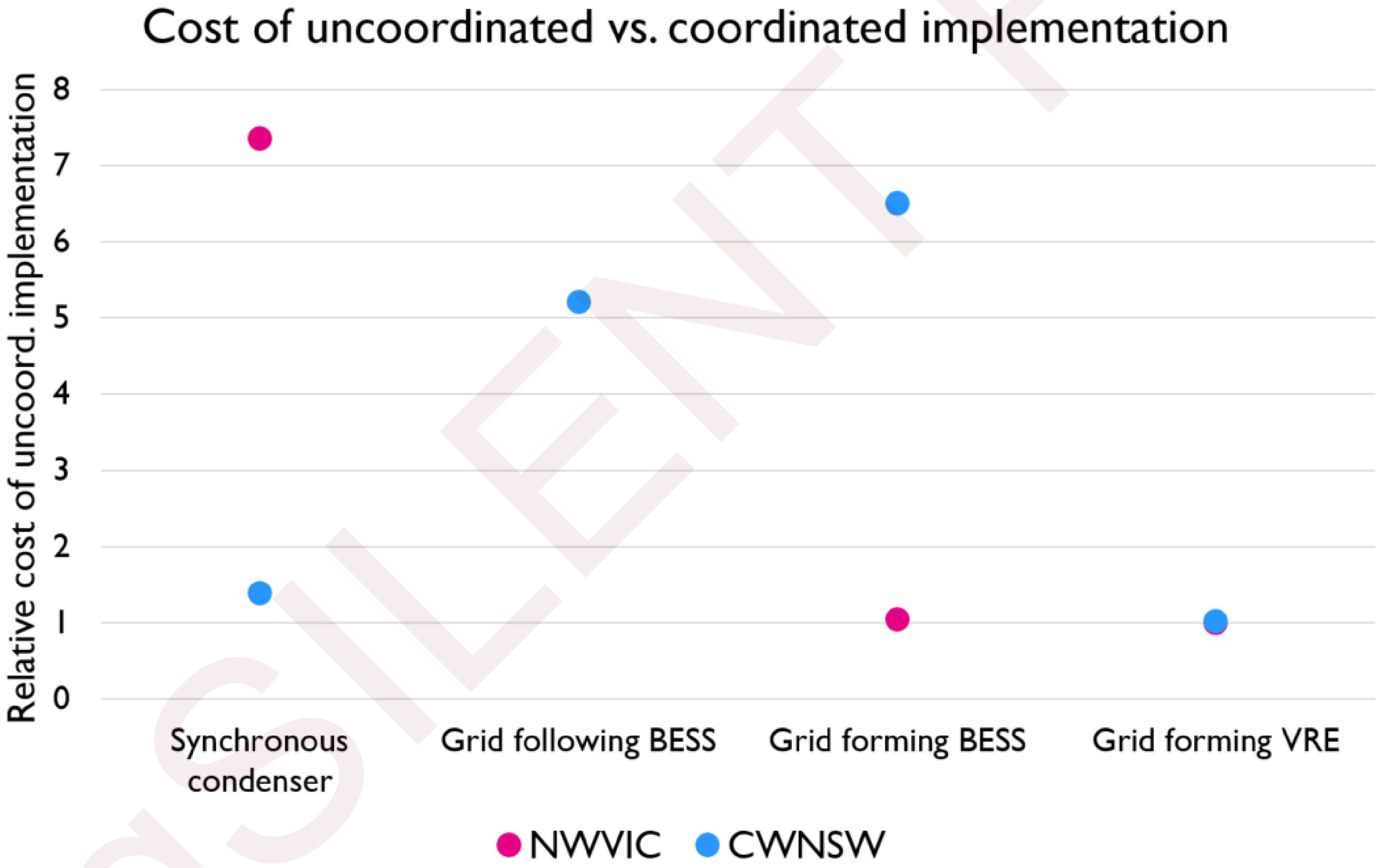
Value of coordination [1]

The impact of coordination on the cost of implementing technology solutions varies considerably between REZs and technology types



Value of coordination [2]

Coordination of the deployment of technology solutions, rather than installing on a site-by-site basis, is a more cost-effective way of integrating VREs and accelerate commercial build-out

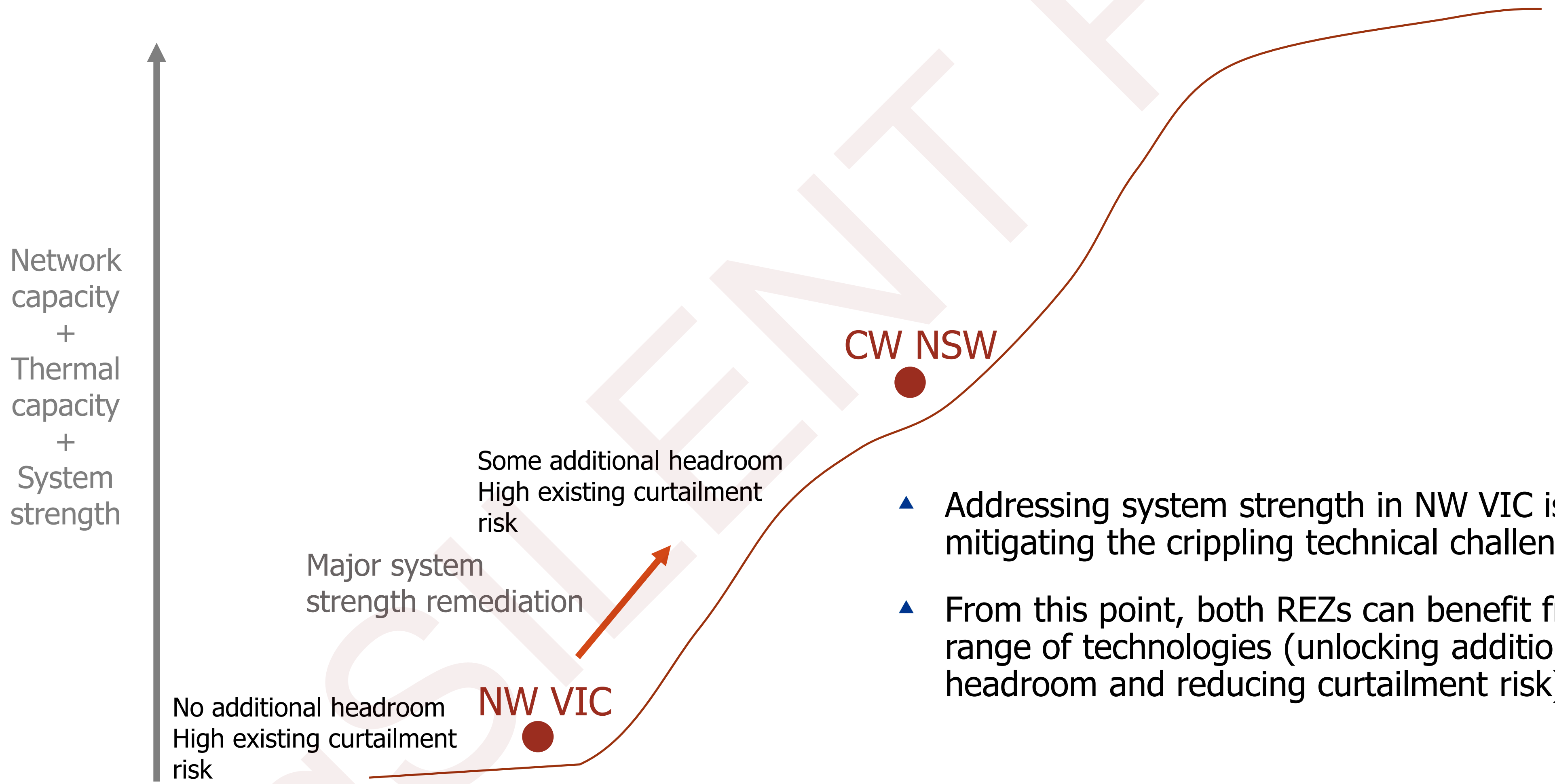


The case study REZs have different network topologies

Attribute	Central West NSW	North West VIC
Classification	Greenfield	Brownfield
Topology	Meshed 132 kV network next to 330 kV strong grid	Single circuit 220 kV radial network
Performance	Slightly limited by thermal and system strength issues	Heavily limited by thermal and system strength issues
Existing and committed generation capacity	940 MW (% curtailment?)	1875 MW (~40% curtailment)
Remaining network capacity	216 MW	0 MW

The case study REZs are at different starting points

These two REZs have recently seen active VRE development with available network capacity being rapidly exhausted. This is leading to increased risk of curtailments and hindering access to the significant remaining potential



- Addressing system strength in NW VIC is key to mitigating the crippling technical challenges
- From this point, both REZs can benefit from a range of technologies (unlocking additional headroom and reducing curtailment risk)

Study summary

- As the starting point can be so different, **a ‘one size fits all’ approach is not appropriate** when considering technology solutions for REZs.
- **Network augmentations are the most effective stand-alone solution** to developing the REZs and avoiding high electricity prices after major coal plant retirements, capable of unlocking more new connection capacity than any technology solution deployed on a stand-alone basis
- **Technology solutions are complementary** to network solutions and can facilitate additional connection capacity beyond that unlocked by network build.
- **A coordinated approach** to implementing technology solutions (scaled and strategically positioned) can reduce the cost of making new REZ capacity available, relative to implementation through an uncoordinated (‘do no harm’-style) approach.
- In the CW-NSW REZ, a number of technology solutions have the potential to efficiently unlock new connection headroom in the near-term.
- In the NW-VIC REZ, the network topology and significant existing technical challenges limit the potential of technology solutions to unlock new connection capacity.
- While this study modelled technology solutions on a standalone basis, it is likely that a suite of technology solutions could be deployed in each REZ

For more information, please find below the link to the ARENA REZ report:
https://arena.gov.au/knowledge-bank/development-of-renewable-energy-zones-in-the-nem/

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