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1 Summary

Together with a robust and defensible Base Case valuation scenario, a number of credible alternative scenarios were modelled for Snowy 2.0. These scenarios fell into two groups: NEM scenarios with a Project value focus, and Snowy Hydro Corporate scenarios with a debt-servicing focus. The value modelling found that Snowy 2.0 provides substantial value under all scenarios except if substantial quantities of new coal generation were to be developed.

1.1 Introduction

The scenarios were selected to best demonstrate both the realistic, expected outcomes and the tail risk around the Base Case valuation.

1.2 Scope and exclusions

Inclusions:

1. Snowy Hydro portfolio modelling to understand under various scenarios the value of the Project over time and uncertainty in Net Present Value (***NPV***) terms; and
2. Valuation - translating economic fundamental analysis of the National Electricity Market (***NEM***) supply-demand trajectory over time into net financial cash flows to derive Project present value.

Exclusions:

1. Snowy Hydro Corporate modelling outcomes (See *Supporting Chapter Five - Market modelling*).

1.3 Activities undertaken

The Snowy Hydro Commercial team has compiled a series of scenario stress test outcomes to demonstrate the value sensitivities around the Base Case value proposition. Specialist third-parties were engaged to maximise the assimilation of best available latest information into the assumption changes.

1. Marsden Jacob Associates (***MJA***) provided economic market modelling;
2. Aurecon provided information on the flexibility of thermal plant; and
3. Macquarie Bank provided financing consultancy.

1.4 Valuation sensitivities and scenarios

The valuation scenarios were undertaken with two different approaches to fit two different strategic objectives:

1. **NEM scenarios** (Project value focus); and
2. **Snowy Hydro Corporate Scenarios** (debt-servicing focus).

The NEM scenarios highlight the uncertainty around market outcomes that primarily affect Snowy 2.0 value. The Snowy Hydro Corporate Scenarios were framed to satisfy the debt-servicing objectives of Standard & Poor's (***S&P***)'s Rating Evaluation Service (***RES***).

A large number of scenarios were modelled to determine the robustness of the Snowy Hydro business case and whether to invest (or not) in the Project. Only the materially important scenarios are reported here.

1.5 Modelling

1.5.1 'NEM' scenarios

Risks to Snowy Hydro (both Snowy 1.0 and Snowy 2.0) and the range of potential revenue streams that would be captured by Snowy 1.0 and Snowy 2.0 formed the basis of the scenarios developed.

The scenarios were a Base Scenario (considered most likely) and alternative scenarios that represented significant changes from the Base Scenario. The Base Scenario was:

1. Consistent with current energy policy and announcements;
2. Incorporated the most likely assessment of economic condition and costs; and
3. Developments and market operations were guided by rational economics.

The scenarios modelled were, briefly:

1. **Base Case** - current State government policy, National Energy Guarantee (***NEG***) (26% reduction by 2030), announced and most likely closures and developments, economically rational entry and exit;
2. **Low Emissions** - stronger policy for emissions, high rooftop Photovoltaic (***PV***);

3. **Coal Early Closure** - all coal plant closed at 50 years;
4. **High Demand** - Australian Energy Market Operator (***AEMO***) 2018 Electricity Statement of Opportunities (***ESOO***) high-demand case;[1]
5. **Hydrology Wet** - increased inflows due to wet climatic conditions;
6. **Hydrology Dry** - reduced inflows due to drought;
7. **High Electric Vehicle (*EV*) Penetration** - percent of EVs on the road (50% by 2030 and 80% by 2040);
8. **Cheap Battery** - accelerated cost depreciation and regulation requirement; and
9. **ISP Case** - this is scenario assumes that the Kerang link is not built.

The Base Case was modelled over the period 2018-19 to 2074-75 on the basis that Snowy 2.0 does not enter, and on the basis that Snowy 2.0 enters 1 July 2025 (ie the 2025/26 year).

A key message from the modelling and results of these scenarios is that NEM market outcomes become increasingly complex and sensitive as the existing coal generators close. Increasingly, the 'layers' of generation with different Short Run Marginal Costs (***SRMC***) that currently exist will be replaced with low marginal cost generation, gas generation and storage (which will likely have the opportunity value of sales at gas generation costs). This results in a price dynamic that is more sensitive to change.

Some of the existing coal power stations could close earlier than has been assumed in the Base Scenario. This could arise from policy changes or from economics associated with aging assets. The implications of coal closing earlier are complex as it involves the response to replacing the firm capacity and the energy production foregone.

The modelling found that Snowy 2.0 provides substantial value under all scenarios except if substantial quantities of new coal generation were to be developed. The Base Scenario sits near the middle of the range for the NPV impact on Snowy Hydro net spot market revenues due to Snowy 2.0 for the Base Scenario and alternative scenarios.

1.5.2 'Snowy Hydro Corporate' scenarios

Five 'Snowy Hydro Corporate' scenarios were modelled:

1. **Base Case** - difference between the value of Snowy Hydro with and without Snowy 2.0;
2. **NEM downside** - lower value of capacity in the NEM;
3. **Hydrology Dry** - long-lasting reduced inflows to the Scheme;
4. **Severe downside capex** - overrun of $1.0 billion or 17%;
5. **Consolidated downside** - NEM downside, capex overrun of $0.5 billion or 8%, and increased cost of funding.

[1] (AEMO 2018).

2 Activities undertaken

The Snowy Hydro commercial team engaged independent experts with third-party specialist skills to maximise access to best available latest information to underpin the Project (aka Snowy 2.0) modelling.

2.1 MJA engagement

MJA advised and provided modelling for Snowy Hydro on the development of the NEM. This included the various scenarios described in the 'NEM modelling' section of this chapter.

See *Supporting Chapter Five* for more detail.

2.2 Thermal coal fleet flexibility

An independent expert's advice and report underpins the assumptions applied to the thermal fleet flexibility used in the the base case.

See *Supporting Chapter Five* for more detail.

2.3 Financing options

An independent expert provided advice with regard to financing options under various 'Snowy corporate modelling' scenarios. These scenarios were built for the RES process with S&P and are described in the 'Snowy Hydro Corporate' scenarios section of this paper.

2.4 Snowy Commercial team

Engagement of third-party specialists enabled Snowy Hydro to evaluate Snowy 2.0 with the maximum feasible robustness. The Snowy Hydro commercial team acted as an interface between market modelling and economics advisers, the financing advisers and the financiers.

3 Valuation sensitivities and scenarios

3.1 Overview

The valuation scenarios were undertaken with two different approaches to fit two different strategic objectives:

3. **NEM scenarios** (Project value focus); and
4. **Snowy Hydro Corporate Scenarios** (Debt-servicing focus).

The NEM scenarios highlight the uncertainty around market outcomes that primarily affect Snowy 2.0 value. The Snowy Hydro Corporate Scenarios were framed to satisfy the debt-servicing objectives of S&P's RES.

3.2 Modelling in 2 parts: 'NEM' and 'Snowy Hydro Corporate' Scenarios

To determine the robustness of the Snowy Hydro business case to invest (or not) in Snowy 2.0, a large number of scenarios were modelled. The materially important scenarios are reported in this chapter. It is important to note that in order to run scenarios, a number of interdependent models must be flexed and sensitised so the materially accurate results are can be reported. This requires coordination of a number of models within the modelling and business case evaluation process. Below is a high level map of the models that the Project has utilised in delivering these scenarios.

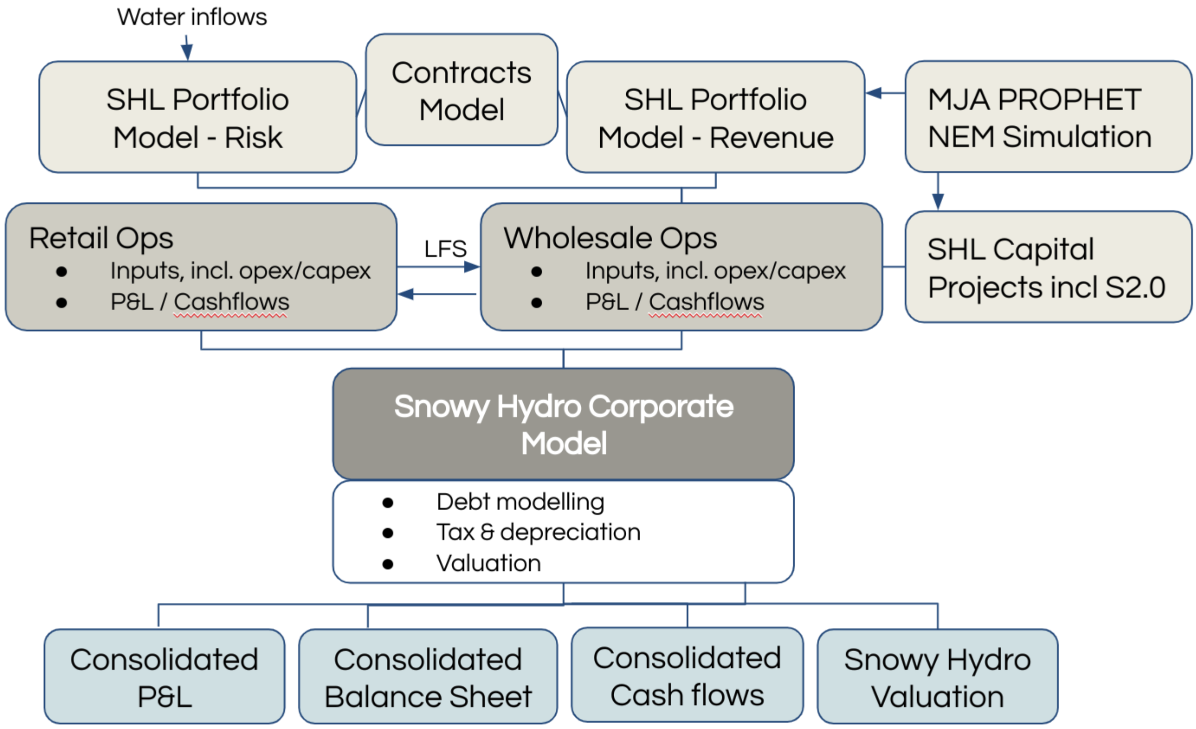


Figure 1: High level map of Snowy Hydro models utilised by the Project

4 Modelling: 'NEM' Scenarios

4.1 'NEM' Scenarios Development

The basis of the scenarios developed was the risks to Snowy Hydro (both Snowy 1.0 and Snowy 2.0) and the range of potential revenue streams that would be captured by Snowy 1.0 and Snowy 2.0 under the scenarios developed.

The range of NEM outcomes needed to recognise the future uncertainties in matters that include demand growth, technology costs, environmental policy, retirement profile of coal generation, entry of additional storage etc.

The 57-year study period meant that the fundamental drivers of market change were required to be identified and explicitly accounted for.

The structure of the scenarios modelled consisted of a Base Scenario and alternative scenarios that represented significant changes from the Base Scenario.

The Base Scenario was considered to be the most likely scenario. The basis of this scenario was as follows:

1. Consistent with current energy policy and announcements;
2. Incorporated the most likely assessment of economic condition and costs; and
3. Developments and market operations were guided by rational economics.

Changes from the Base Scenario considered for modelling were based on a review of future uncertainties, their likelihood, and the size of the potential impact to Snowy 1.0 and Snowy 2.0 revenues.

Future uncertainties that presented risks to Snowy Hydro (both positive and negative) included the following:

1. Electricity demand growth;
2. The impact of Electric Vehicle (***EV***) uptake;
3. Emissions abatement policy beyond the 26% reduction by 2030 (which is projected to be met based on current policy);
4. Profile and regulation of coal plant closures (such as indicated in the Finkel Review);[2]
5. Costs and economics of storage (both in front and behind the meter);
6. Costs of solar generation and wind generation;
7. Commodity prices – gas and coal; and
8. Changed to water inflows to hydro plant across the NEM including Snowy 1.0.
9. Transmission risk, specifically the timing and commitment to develop the Kerang link in time for Snowy 2.0 commissioning in 2025.

From this review the scenarios modelled (including the Base Scenario) are presented in Table 1. They are intended to represent a balanced spread of outcomes that account for the potential changes that can occur in the NEM.

The Slow Demand growth scenario was not modelled.[3] The reasons for this were as follows:

1. The Base Scenario had a lower demand outlook than the Neutral growth scenario 2018 ESOO by AEMO. This difference was quite substantial post 2030; and
2. The basis of the 2018 Slow demand growth outlook was not considered suitable for modelling in light of the increasing Australian population and energy demand.

[2] (Finkel et al. 2017).
[3] In comparison to the Neutral scenario, AEMO state the following in the ESOO regarding the Slow scenario:

> 'reflects a lower forecast for new dwellings, electric vehicles, energy-efficiency impacts, and less residential consumption in response to retail price rises, compared to the Neutral pathway. Under the Slow change scenario, annual delivered consumption growth remains relatively flat in the short term, followed by a slight increase, mainly in the latter half of the outlook period. This results in growth of 11 % (or 0.5% annual average) over the 20-year forecast.'

In all the scenarios modelled Snowy 3.0 is assumed not developed. The reason for this is to value Snowy 2.0 on the basis of opportunity costs excluding other Snowy Hydro developments.

The scenarios are each described in the sections that follow.

4.1.1 Scenarios Modelled

The scenarios were developed from a review that included demand outlook, distributed PV and storage, large-scale technology and commodity costs, potential energy policy, and investment risk.

The review concluded that irrespective of future energy policy (particularly emission limits), all scenarios will have an underlying narrative of increasing Variable Renewable Energy (***VRE***) supported by firming, where firming will be provided by existing dispatchable generation (which will decrease as existing power stations close) and new entry storage and gas generation. This trend may be accelerated or delayed by the early closure of coal power stations or by extending coal generation (through delayed closure of existing power stations and/or new coal power stations). Without pricing emissions, which is assumed in all scenarios, the long-term mix of generation would tend to a lower level of VRE and storage and a higher level of emissions.

The Base Scenario was developed to be consistent with the above. Its assumptions were based largely on public domain data which included current energy policy, announced developments, AEMO demand projections and transmission developments identified in the Integrated System Plan (***ISP***). Gas costs were based on an assessment by MJA based on a report commissioned by Snowy Hydro. The Base Scenario was considered to represent a central scenario.

From the Base Scenario, eight alternative scenarios were developed and modelled. These represented potential changes to demand growth, hydrological conditions, future energy policy, coal power station outlook, and future capital costs.

The scenarios included are listed in Table 1.

Scenario Name	Change from	Description
Base Case		1. Current policy - Large-scale Renewable Energy Target (***LRET***), Victorian Renewable Energy Target (***VRET***) and QLD Renewable Energy Target (***QRET***) 2. Proposed National Energy Guarantee (***NEG***) (26% emissions reduction by 2030) 3. Announced generation closures and entry 4. Most likely coal closure program (Eraring, Yallourn, Vales Pt) 5. Most likely new pumped-hydro development 6. No emissions reduction target post 2030 7. Rational economics (entry and exit based on economics)
Low Emissions	Base	1. Policy for emissions – 45% by 2030, 80% reduction by 2050 2. High rooftop PV (with base assumption on batteries) 3. Basslink II developed (600 megawatt (***MW***) link from TAS to VIC)
Coal Early Closure	Base	1. All coal plant closed at the operational age of 50 years 2. Gladstone 2026, Loy Yang A 2038.
High Demand	Base	1. Apply the AEMO high demand case from the 2018 ESOO - Fast Scenario
Hydrology Wet	Base	1. Wet climatic conditions increase inflows and thus generation for all east coast hydro 2. Snowy Hydro modelling (pre '25): CP19 Wet sequence 3. MJA modelling (post '25): + 10% inflows p.a.
Hydrology Dry	Base	1. Drought reduces inflows and thus generation to all east coast hydro facilities 2. Snowy Hydro modelling (pre '25): CP19 Dry sequence 3. MJA modelling (post '25): - 10% inflows p.a.
High EV Penetration	Base	1. 50% by 2030; 80% by 2040 (% of cars on the road) 2. Two charging profiles were modelled
Cheap Battery	Base	1. Double battery cost curve depreciation rate 2. Additional regulatory requirement for battery installation to accompany VRE development.
ISP Case: Kerang is never built	Base	1. Transmission risk has been considered as a potentially severe risk to the role Snowy 2.0 is able to play in the NEM. 2. The ISP case, which assumes that Kerang Link is never built

Table 1: MJA scenarios modelled

4.2 'NEM' Scenarios results - executive summary

4.2.1 General

There is significant uncertainty and increasing risk to the NEM as the existing coal fleet closes and this is replaced by VRE, gas generation and storage. These risks include the variability of energy production from VRE over both short and long-time scales, coal plant performance, availability of gas plant, and demand outlook.

Snowy 2.0 provides capacity and deep storage central to addressing these risks.

The changing nature of the NEM and the dynamics of energy arbitrage mean that the value derived from Snowy 2.0 is subject to and sensitive to many factors.

4.2.2 Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Table 2 presents the total NPV of net spot market revenues for the 'without Snowy 2.0' and 'with Snowy 2.0' cases and the change in net spot market revenues due to Snowy 2.0.[4]

Case	Without Snowy 2.0	With Snowy 2.0			Change
Assets	**Snowy 1.0**	**Snowy 1.0**	**Snowy 2.0**	**Total**	
Base	11,213	10,717	4,139	14,856	3,643
Low Carbon	12,600	12,473	4,948	17,421	4,821
Coal Early Closure	13,994	13,059	4,675	17,734	3,740
High Demand	12,581	11,610	4,581	16,191	3,610
Hydrology Wet					
Hydrology Dry	10,850	10,238	4,162	14,400	3,550
High EV Penetration (Flat)	12,179	11,347	4,630	15,977	3,798
High Battery	10,991	10,612	3,776	14,389	3,398

Table 2: Scenarios and Cases – Net Market Spot Revenues in AUD million [Source: MJA]

4.2.3 Base Scenario

A summary of the annual outcomes for the Base Scenario over the period 2018-19 to 2046-47 is shown in Figure 2 below. Shown are:

1. NSW annual average spot prices;
2. Daily average NSW spot prices for the years 2018-19, 2027-28, 2037-38, 2046-47;
3. For the 'with Snowy 2.0' case the installed plant capacity;
4. The change in installed capacity in moving from the without Snowy 2.0 case to the 'with Snowy 2.0' case;
5. For the 'with Snowy 2.0' and 'without Snowy 2.0' cases, the NEM carbon emissions; and
6. Snowy 2.0 generation and pumping volumes and average pumping and generation prices.

Based on modelling, the period 2047-48 to 2074-75 was taken to be an extension of the 2044-45 to 2046-47 years.

[4] The change is the net revenues for the With Snowy 2.0 case less the net revenues for the 'without Snowy 2.0' case.

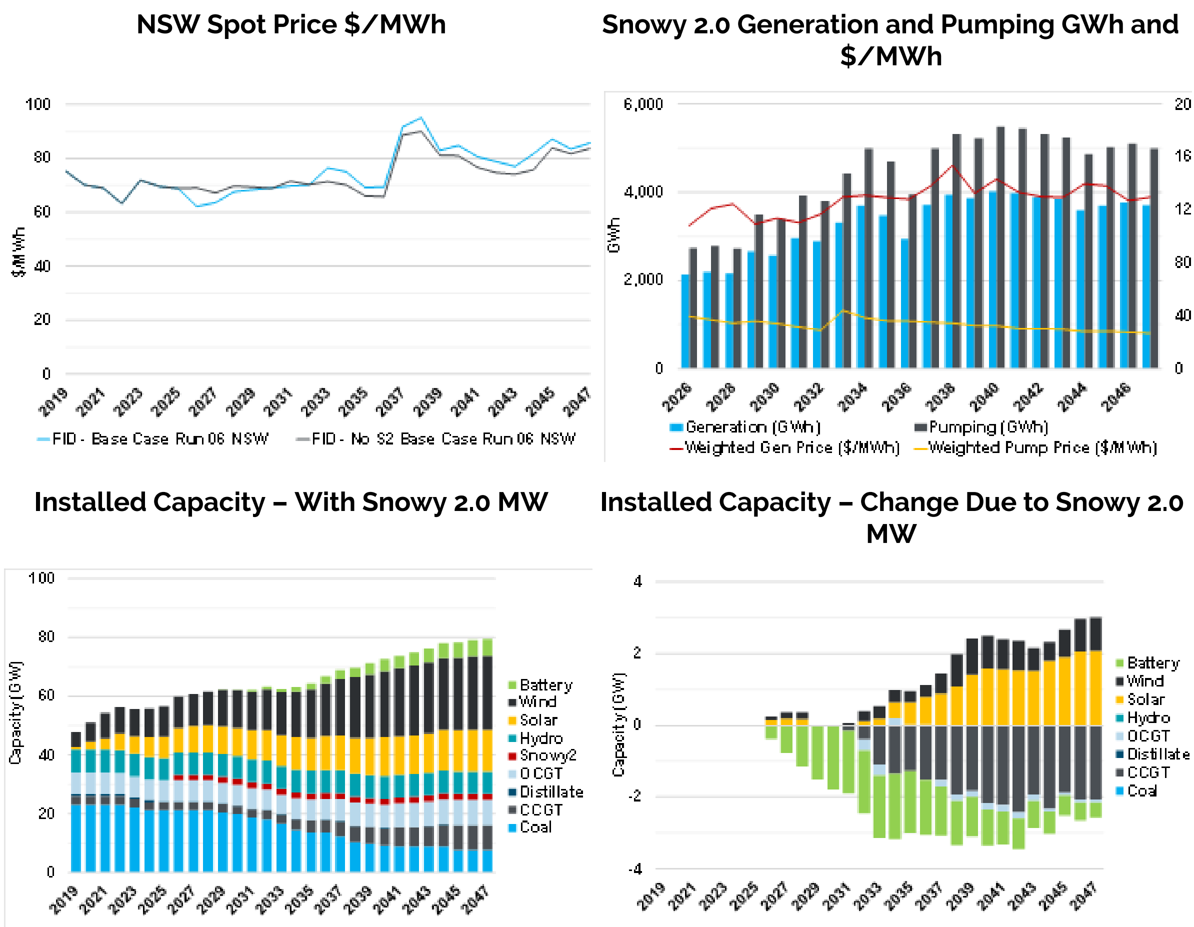


Figure 2: Base Scenario - Modelling Outcomes 2019 to 2047 [Source: MJA]

The period 2047-48 to 2074-75 was taken to be an extension of the 2044-45 to 2026-47 years.

Observations concerning the Base Scenario

Spot prices:

1. The average NSW spot price in 2018-19 is lower than in 2017-18 reflecting the amount of VRE that is entering the NEM;
2. The average NSW spot price increases by about $10/MWh when Liddell closes. The immediate years after this have the average annual NSW spot price flattish, reflecting flat demand and continuing VRE development (particularly in QLD);
3. Post 2032, the closure of coal power stations results in spot price volatility and a general increase in average annual spot prices post-2040. The higher average annual spot prices reflect gas generation and storage selling at prices shadowing gas generation prices (and clearing the market more often);
4. Snowy 2.0 results in a reduction of spot prices until the early 2030s reflecting an excess of capacity. After this Snowy 2.0 results in slightly higher spot prices. This reflects more variability due to a higher level of VRE, reduced gas plant, reduced coal plant minimum generation (mingen)

levels during low price periods, and higher demand due to pumping. This study does not investigate the further portfolio options that Snowy Hydro owns such as the real option provided by 'Snowy 3.0' as the 2030s approach.

Installed generation:

1. VRE (solar and wind) increases over the study period. There are two reasons for this:
    a. Economics – spot market revenues available to VRE compared to costs. This reflects the firming provided by the flexibility of the existing dispatchable generation. As coal power stations close the firming available without new investment reduces; and
    b. Replacing the closing coal plant. New generation is required and the options without new coal generation are base load gas generation or VRE with firming provided by peaking gas generation and battery storage;
2. Snowy 2.0 provides support and firming for VRE generation. It results in about 3,000 MW of additional VRE generation and a reduction of about 2,000 MW of gas generation (mainly Combined Cycle Gas Turbine (***CCGT***)). Snowy 2.0 results in a reduction of about 1,000 MW of batteries in the initial years of Snowy 2.0 operation, with this reduction diminishing due to the additional VRE that enters.

Emissions:

1. Emissions reduce due to coal power station closures and no new coal power stations being developed;
2. Emissions level off in the 2040s at about a 65% reduction (compared to 2005 levels). This reflects the economics of battery storage that would be required to support the higher levels of VRE required to further reduce emissions, ie battery economics would need to significantly improve in order to get a larger reduction in emissions. The level of additional cost reduction required would appear to make this most unlikely.

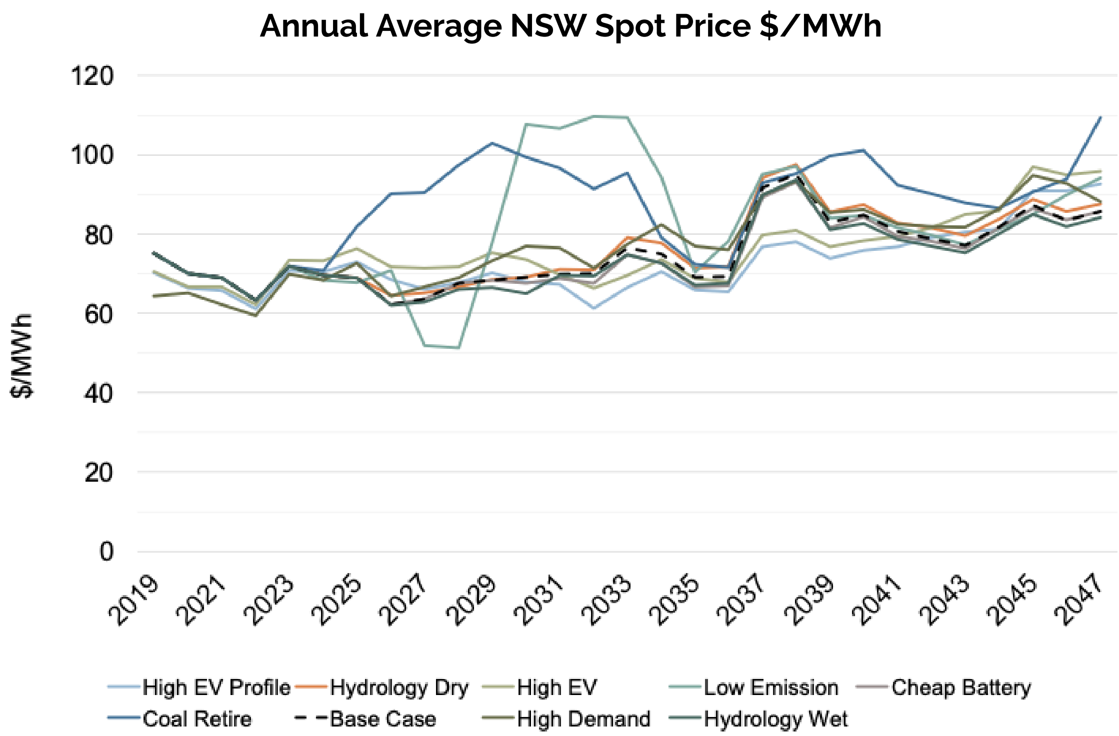
Snowy 2.0 operation:

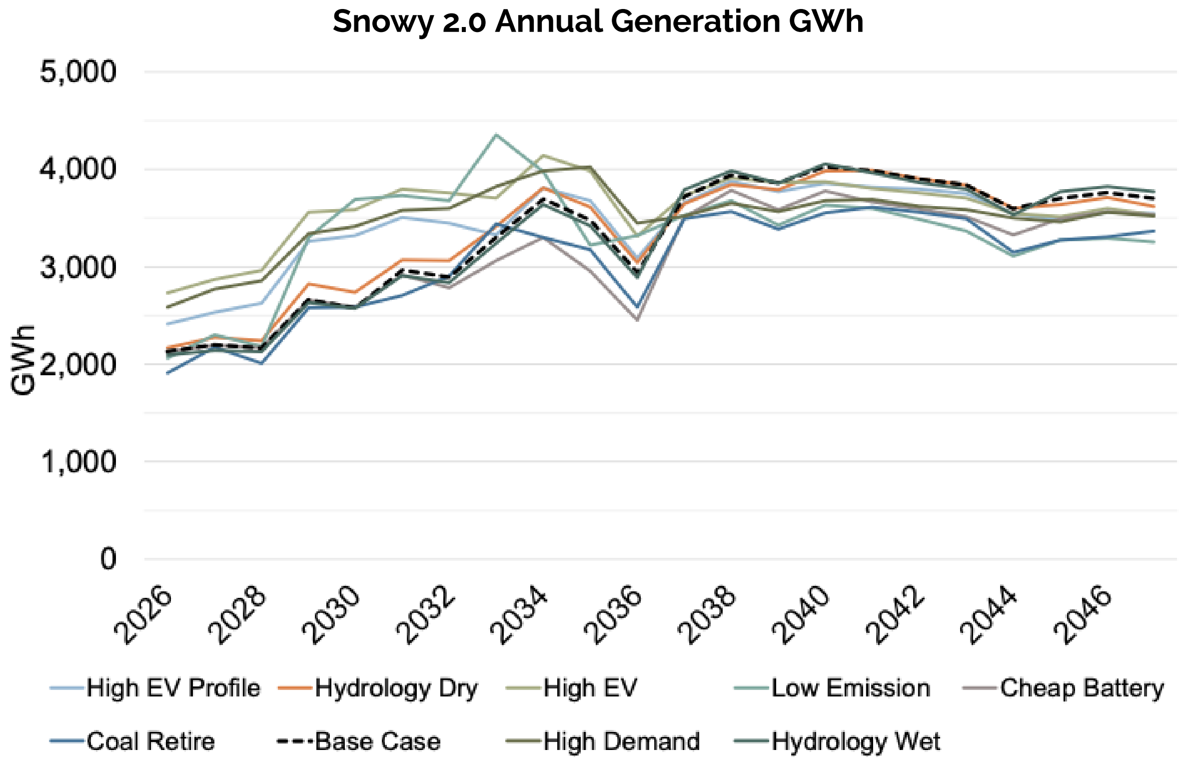
1. Snowy 2.0 annual generation and pumping volumes are related by the Round Trip Efficiency (***RTE***) which averages about 76% at commissioning;
2. Snowy 2.0 pumping volumes increase as VRE increases (incentivised by coal generator closures);
3. Coal generation closure with VRE unchanged reduces pumping opportunities and consequently Snowy 2.0 generation;
4. The average price of pumping decreases except for a 'kink' in 2036 which is due to the closure of Eraring;
5. From the mid-2040s onwards the closure of coal power stations acts to slightly reduce pumping volumes as a high proportion of the coal generation closed is replaced by gas generation. This reflects the volumes and associated costs of storage that would be required to replace gas generation (as the need for firming capacity increases).

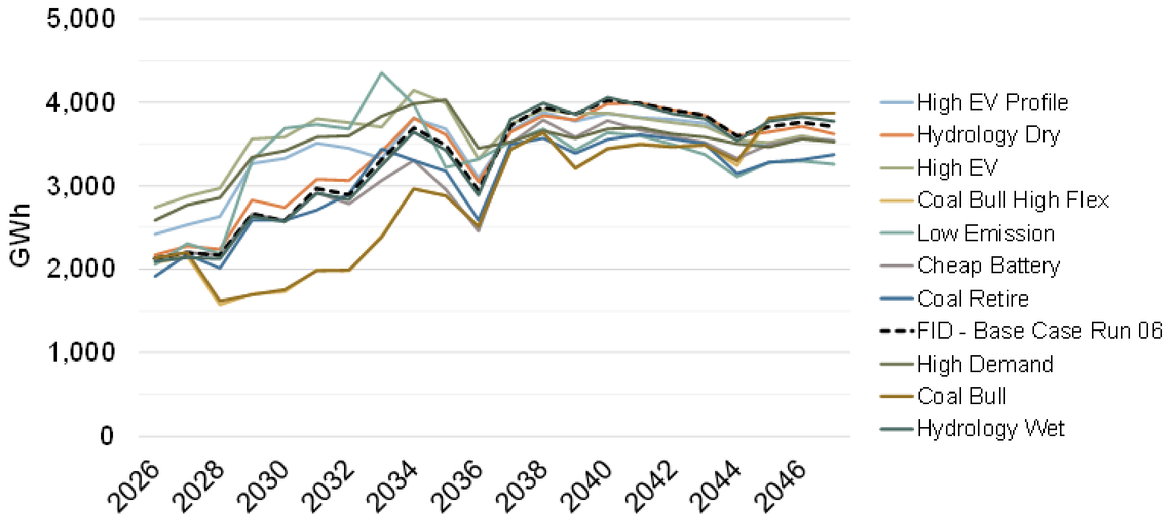
4.2.4 Alternative Scenarios

Summary

The alternative scenarios were described in Table 1. Figure 3 shows for the base and alternative scenarios, the annual average values for the NSW spot price ($/MWh), Snowy 2.0 generation (GWh), and the price received by Snowy 2.0 for generation ($/MWh).




Snowy 2.0 Annual Generation GWh
5,000
4,000
3,000
2,000
1,000
0
GWh
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
High EV Profile
Hydrology Dry
High EV
Low Emission
Cheap Battery
Coal Retire
Base Case
High Demand
Hydrology Wet


5,000
4,000
3,000
2,000
1,000
0
GWh
2026
2028
2030
2032
2034
2036
2038
2040
2042
2044
2046
High EV Profile
Hydrology Dry
High EV
Coal Bull High Flex
Low Emission
Cheap Battery
Coal Retire
FID - Base Case Run 06
High Demand
Coal Bull
Hydrology Wet

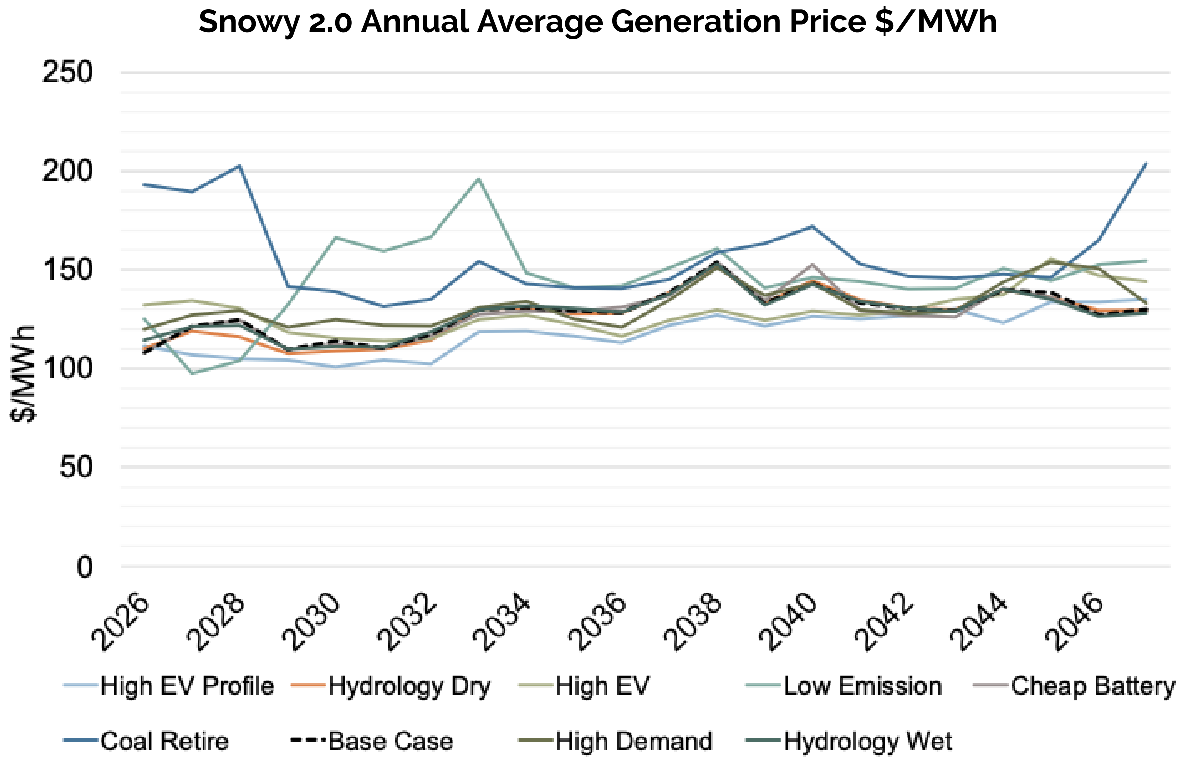


Figure 3: Modelled Scenarios – NSW Spot Price and Snowy 2.0 Generation and Average Price of Generation [Source: MJA]

A key message from the modelling and results of these scenarios was the increasing complexity and sensitivity of NEM market outcomes as the existing coal generators close. Increasingly, the 'layers' of generation with different Short-Run Marginal Costs (***SRMC***) that have and currently exist will be replaced with low marginal cost generation, gas generation and storage (which will likely have the opportunity value of sales at gas generation costs). This results in a price dynamic that is more sensitive to change.

The NPV impact on Snowy Hydro net spot market revenues due to Snowy 2.0 for the Base Scenario and alternative scenarios are shown in Figure 4. The Base Scenario sits near the middle of the range.

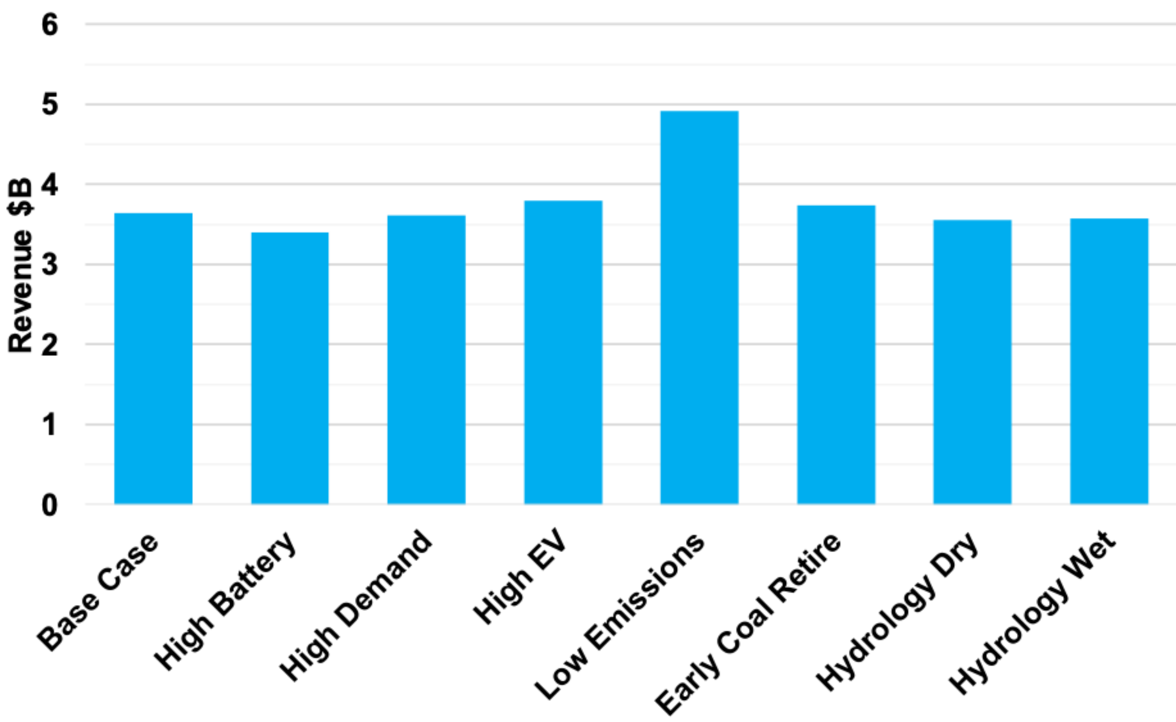


Figure 4: Snowy 2.0 NPV of Net Spot Market Revenues [Source: MJA][5]

The key observations from the alternative scenarios are briefly presented for each of the scenarios.

Low Emissions

1. Before 2030:
    a. Compared to the Base Scenario the Low Emissions Scenario requires additional coal closures, addition VRE for energy replacement and firming support including Basslink II (600 MW);
    b. Development time means additional VRE is needed prior to the date of the coal closures – this results in lower prices during this period;
    c. The quantity of coal closure results in less dispatchable generation and higher prices after the coal plant closes; and
2. After 2038, an 80% emissions reduction by 2050 requires coal closure and replacement by a larger component of VRE than in the Base Scenario. This increases the requirement of storage, with storage hours over 18 hours.

Transmission

1. The development of the proposed new interconnection between SA-NSW, VIC-NSW and NSW-QLD will, through increased diversity and reserve sharing, assist in reducing the total firming required across the NEM to support a higher level of VRE.

Coal Early Closure

1. Similar dynamic to the Low Emissions Scenario prior to 2030 and in the late 2040s, with the difference that there is no requirement for VRE from an

[5] NPV period: 2018-19 to 2074-75. NPV discount rate: 4.55% real (pre-tax).

emissions perspective. This reduces the VRE developed as replacement generation; and

2. The early closure of Loy Yang A (2038) reduces pumping volume but increases the hours that gas generation sets the spot price.

High Demand

1. Demand growth (as opposed to flat demand) has spot prices increasing. In the event that higher demand growth was not projected, this could result in a shortage of capacity;
2. A high level of generation development including battery storage;
3. Emissions are higher, requiring greater investment in VRE and associated firming assets if emissions are to be limited;
4. Snowy 2.0 brings on more VRE than in the Base Scenario; and
5. Both Snowy 1.0 and Snowy 2.0 have increased revenues.

Hydrology Changes Wet and Dry

1. Changed Snowy 1.0 generation volumes;
2. Changed Snowy 1.0 and Snowy 2.0 generation volume are those components which have the lowest value (ie near the value of water); and
3. NEM prices reflect all NEM hydro generation volumes being changed.

High EV Penetration

1. Demand increase is substantial by 2040 – equivalent to about a 4,000 MW base load power station;
2. Results in a substantial increase in new generation by 2036 compared to the Base Scenario. This lessens the relative size of the Eraring closure in 2032 and results in a lower increase in revenues when compared to the Base Scenario;
3. Demand will have a level of control and a proportion of batteries may be 'aggregated' and may have some central control;[6]
4. A flat battery charging (ie demand) profile increases Snowy 1.0 and Snowy 2.0 revenues across all years except when Eraring closes; and
5. A battery charging profile that has more charging concentrated in spot price periods reduces spot price spread and reduces pumping volumes. This reduces Snowy 1.0 and Snowy 2.0 revenues.

High Battery

1. The reduction in battery costs (given by a doubling in the rate of cost battery module cost reduction) was not sufficient to have battery entry economic. However, this would reduce the cost of regulated battery entry and an increase in battery entry of 3000 MW (4 hours storage) compared to the Base Scenario was assumed. Two cases were modelled for this scenario:
    a. The increased level of battery entering does not invoke a market response:
        i. Provides increased competition to Snowy 2.0;
        ii. The relative shallow level of storage hours limits the impact;

[6] This terminology is use by AEMO.

iii. The level of arbitrage prices and volumes are reduced; and
iv. Lower Snowy 1.0 and Snowy 2.0 revenues.

b. The increased level of battery entering does invoke a market response of additional VRE and reduced gas generation:
   i. The response is less than that due to Snowy 2.0 due to the limited storage of the batteries compared to Snowy 2.0; and
   ii. The market response reduces the impact of the increased battery installation.

ISP Kerang not built

The base case is based on the belief that the construction of Kerang link will occur by 2025, necessitated by key economic drivers for renewable developments and to maximise the efficiency of the interconnected NEM. This scenario assumes that Kerang link is never built and demonstrates the effect on NPV of the Group compared to the base case.

4.3 'NEM' Scenarios results - detailed summary

4.3.1 Overview

This section summarises the finding of the study through a narrative description of the basis and risk for Snowy 2.0, followed by a graphical presentation of the modelling results and the NPV values for scenarios modelled.

4.3.2 Summary of Snowy 2.0 and requirement

A summary of the study findings that relate to the basis for and economics of Snowy 2.0 is presented below. This is presented under the headings of:

1. VRE Operation in the Current NEM;
2. NEM Transformation – Capacity and Energy Requirements;
3. Snowy 2.0 and Impact to NEM Development;
4. Economic Modelling of Snowy 2.0.

VRE Operation in the Current NEM

The NEM

The NEM is undergoing a transformation associated with the rapidly changing economics of generation, a recognition of the need to reduce carbon emissions in the long-term, and aging coal generators of which a substantial number will close by the mid-2030s.

VRE Entry To date

Up until recently (ie 2018), VRE economics required additional revenues other than that provided by spot energy revenues. The Renewable Energy Target (***RET***) and LRET schemes were designed to provide this additional revenue stream, and the VRET and QRET schemes have been respectively introduced by the VIC and QLD State governments to continue VRE developments post 2020.

VRE cost reductions and increasing spot price levels (reflecting less coal generation and high gas prices) now has VRE economic on spot energy sales alone, and new VRE is being planted on the basis of this new economic reality.

To date, except in SA, the accommodation of VRE in the NEM has not been difficult. This is because the NEM has had enough dispatchable and firm capacity to absorb the variability of VRE production. Expressed differently, the NEM has had sufficient firming capacity.

NEM Transformation – Capacity and Energy Requirements

New Generator Options and VRE Entry post 2025

From a supply reliability perspective, as the coal power stations close (which could see all existing coal generators close by the mid-2040s) it will be necessary to replace both the dispatchable and firm capacity (MW) and energy production (MWh) that was provided by these generators. The options to replace this capacity and energy production were identified as:

1. **VRE (solar and wind generation)** - This provides energy but only a relatively small amount of capacity that can be relied upon;
2. **Gas generation** - This provides both firm capacity and energy but produces emissions, noting that emissions are about half that of black coal generation; and
3. **Storage** - Provides dispatchable and firm capacity noting that the latter would require a storage duration of 24 hours or more.

New coal power stations are not included in the above list. The reasons for this are that new coal generation is becoming increasingly unlikely (each year) due to factors that include cost, public and industry preference, the lending policies of banks regarding coal power stations, and global agreements on emissions.

However, the study did recognise that unlikely events can occur, and a scenario was modelled that had new coal generators developed.

Changing NEM and Transmission

The transformation to increased levels of VRE will result in changed locations of generators as well as associated changes in power flows across the grid. This will increase the need and value of transmission that provides for capacity support between regions.

This is understood as follows. In the absence of VRE, interconnection capacity is and has been used to capture both the diversity that results from regional maximum demands occurring at different times and generator failures in different regions occurring at different times. Increasing levels of VRE will result in increasing and more frequent periods where one region has a high level of VRE output and the neighbouring region has a low level of VRE output. The size of the VRE variations between regions will increase the value and need for upgraded transmission between regions to maximise the benefits of geographical diversification.

The AEMO ISP recognised the need for upgraded transmission between all regions. This study considered that upgraded transmission is required regardless of whether Snowy 2.0 is developed or not.

Firming - Dispatchable and Firm Capacity

As more VRE enters and coal generators close, the ability of the power system to 'absorb' the VRE energy will decrease (ie there will be insufficient 'firming capacity'). Increasing VRE and reducing thermal generation will require increasing amounts of new dispatchable and firm capacity.

This study highlighted the need to distinguish between dispatchable capacity and firm capacity. Dispatchable capacity is that which is controllable (either up or down) and firm capacity is that capacity which is both dispatchable and which can be relied upon to be available. In relation to gas and storage generation:

1. Gas generation provides firm capacity (the issue of firmness in a 5-minute energy settlement market is noted, and price risk may require some Open Cycle Gas Turbine (***OCGT***) plant to have modifications made); and
2. Storage generation with limited hours of storage does not provide firm capacity as it may not be available to generate when needed. The study assessed that firm capacity from storage requires at least 24 hours of storage.

Table 3 below summarises the provision of dispatchable capacity and firm capacity by the different generator types.

	Gas OCGT	Gas CCGT	Coal	Pumped Hydro > 24 hrs storage	Hydro (not run of river)	Wind	Solar	Batteries < 24 Hrs Storage	Batteries > 24 Hrs Storage	Demand Side < 2 Hours
Dispatch-able	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Firm	Y	Y	Y	Y	Y	N	N	N	Y	N

Table 3: Provision of dispatchable capacity and firm capacity by different generator types

VRE Output Uncertainty

Modelling has shown that the uncertainty of VRE output is such that the total variation in energy production increases over increasing time periods (ie daily, weekly, monthly, seasonal, yearly). Capturing the variation in VRE energy output requires days of storage in order that periods of days to weeks of high VRE can be stored and periods of days to weeks of low VRE can be covered (and this relates to firm capacity).

Snowy 2.0 and Impact to NEM Development

'No Snowy 2.0' - Replacing the closing Coal Power Stations

In the absence of Snowy 2.0 the replacement of the closing coal power stations with VRE, gas generation and storage would occur as follows:

1. Using VRE to replace the lost energy production from the closed coal generators;
2. Using dispatchable generation (most notably gas) to fill in the gaps when VRE is not generating:
3. Gas generation does not address the issue of capturing 'spilt' VRE generation and thus has an economic limit on this nature of firming. Taken by itself, firming with gas generation can be viewed as gas generation using VRE to minimise gas use;
4. Using battery storage to capture VRE generation that would spill and using it when needed. Not capturing this generation would mean VRE generators would increasingly provide less generation to the market resulting in increased costs of the usage energy from VRE. This would be reflected in decreasing prices VRE would receive from the spot energy market, which would be increasingly lower compared to average spot price levels. The substantial 'discount' solar and wind generation receives on spot prices would present a significant hurdle to VRE economics;
5. The cost and limited hours of batteries mean that they can only capture part of the daily variation in VRE and do not provide firm capacity; and
6. The outlook is that even with the projected reduced costs of batteries, the level of storage required means that gas generation will be required for firm capacity and to address the majority of the variations in VRE output.

Snowy 2.0 Quality and Value Provision

Snowy 2.0 is a long-life asset that provides 2,000 MW of dispatchable and firm capacity, conservatively 175 hours of storage and is centrally located. The quality and value relationships include:

1. The central location that provides for:
    a. Maximum consumer access;
    b. NEM wide balancing of VRE;
    c. Security against critical transmission outages; and
    d. Additional value to upgraded transmission between SA-VIC-NSW-QLD (the transmission developments identified in the AEMO 2018 ISP between NSW-VIC-SA are considered needed regardless of Snowy 2.0 development as they support the Renewable Energy Zones (***REZ***) and interregional transmission limits necessary to address the closing coal plants).
2. The large level of storage (175 hours) that provides for energy security and firm capacity against extreme market conditions, both of which will become of increasing value to risk mitigation in the future;
3. The flexible operating nature that provides for increased market stability and efficiency:
    a. Providing pumping demand (of up to 2,000 MW) in response to the changing availability of surplus coal and surplus VRE, and generation operating in response to spot price signals and replacing

gas plant and batteries that would have been developed and used; and
b. Such operation directly supports the development of new VRE and emissions reductions.

'With Snowy 2.0' - Replacing the closing Coal Power Stations

Snowy 2.0 would influence the operation of and asset mix that replaces the closing coal power stations as follows:

1. Significantly more 'spilt' VRE output would be captured thereby improving the economics of VRE entry. Additional VRE generation would be developed. The diversity of VRE output means that Snowy 2.0 would provide for significantly more than 2,000 MW of additional VRE to enter;
2. The firm capacity provided by Snowy 2.0 would provide for about 2,000 MW less of gas generation (CCGT and OCGT) to be developed; and
3. Less battery storage would also be needed, although the reduction in battery storage would reduce as battery costs become lower late in the study period.

The net result is improved market efficiency, more reliable market operation, and lower emissions.

Economic Modelling of Snowy 2.0

Snowy 2.0 Risks and Economic Assessment

Like any investment there are risks associated with the Snowy 2.0 development. With the long-term need for Snowy 2.0 established, these risks relate to the transition period to high VRE and low coal generation and competitors to firming services. These risks were categorised as follows:

1. Factors that delay the need for new storage:
    a. Lower demand growth;
    b. Later retirement of coal power stations;
    c. Lower development of VRE; and
    d. Higher development of gas generation.
2. Factors that reduce the revenue received by storage:
    a. Increased flexibility of existing coal generators;
    b. Lower gas costs;
    c. Increased battery uptake (in front and behind the meter); and
    d. Earlier development of Basslink II (Hydro Tasmania pumped hydro project).
3. Factors pertinent to Snowy 2.0:
    a. Delayed transmission development between NSW/VIC/QLD reduced the value of Snowy 2.0; and
    b. Drought increases the value of Snowy 2.0.

The economic and risk assessment of Snowy 2.0 was undertaken through the development and modelling of the NEM under different development scenarios, and for each scenario under two cases, one that assumed Snowy 2.0 was not developed and one that assumed Snowy 2.0 was developed. The scenarios modelled were as follows:

1. A Base (or central) Scenario that assumed the most likely outlooks of demand growth, capital and fuel costs, coal generator closures, and current policy;
2. Changes to the Base Scenario (each modelled separately):
    a. Higher level of demand growth;
    b. Lower and higher levels of hydro water inflows;
    c. Additional battery storage enters;
    d. New coal generation is developed, and existing coal generators increase the flexibility of their operation;
    e. Earlier retirement of some of the existing coal generators; and
    f. Increased EVs projection.

From this modelling the benefits to the NEM and Snowy Hydro associated with developing Snowy 2.0 were obtained.

Snowy 2.0 benefits to the NEM

On a NEM-wide basis the modelling found that Snowy 2.0 would directly and substantially contribute to the trilemma issues of reliability, price, and emissions reduction as the existing coal fleet closes.

The dynamic of this involved:

1. Snowy 2.0 providing replacement firm capacity and energy production;
2. The replacement energy production initially uses spare coal generation as well as VRE generation, and this transitions to mostly spare VRE output as the coal plant closes; and
3. Snowy 2.0 results in additional VRE development and less gas generation development and use.

Snowy 2.0 benefits to Snowy Hydro

Snowy Hydro would capture a substantial amount of the value provided by Snowy 2.0. The modelling findings on the value Snowy 2.0 would provide to Snowy Hydro are as follows:

1. The central case (Base Scenario) has the NPV impact on Snowy Hydro net spot market revenues due to Snowy 2.0 at $3.643 billion (period 2018-19 to 2074-75).[7] This excluded contract sales revenues, which are very substantial;
    a. From the nine scenarios modelled, the NPV impact on Snowy Hydro net spot market revenues due to Snowy 2.0 have seven scenarios in the range $3,398 billion to $3,740 billion. The one outlier is the ow

[7] The impact of Snowy 2.0 on Snowy Hydro is given by the difference of Snowy Hydro net spot market revenues between the 'with Snowy 2.0' case and the 'without Snowy 2.0' case.

carbon emissions scenario (45% by 2030, 80% by 2050) which had an NPV of $4,821 billion.

2. The multi-day storage provided by Snowy 2.0 will be of increasing value as the percentage of VRE in the NEM increases;
3. The impact of Snowy 2.0 on Snowy Hydro is complex, as the impact of Snowy 2.0 could result in Snowy 1.0 revenues being either lower or higher than they would have been otherwise, depending on market developments;
4. The sensitivity of spot price outcomes (and net spot market revenues to Snowy Hydro) to changes will increase as the existing coal generators close; and
5. The impact of reduced hydro water inflows was not significant to the value provided by Snowy 2.0. This reflects that Snowy 2.0 operation is not reduced, it is the lowest value Snowy 1.0 generation that is reduced and reduced hydro inflows across all NEM would result in slightly higher spot prices.

4.3.3 Modelling Result Summary

The figures and tables below present the following average annual figures for all scenarios:

1. Snowy 2.0 generation and pumping volumes (Figure 5);
2. Snowy 2.0 generation and pumping weighted prices (ie the average price received for generating and average price paid for pumping) and the NSW spot price (Figure 6);
3. NPV Net Spot Market Revenue (Table 4); and
4. Change in Snowy Hydro Net Spot Market Revenue (Table 5).

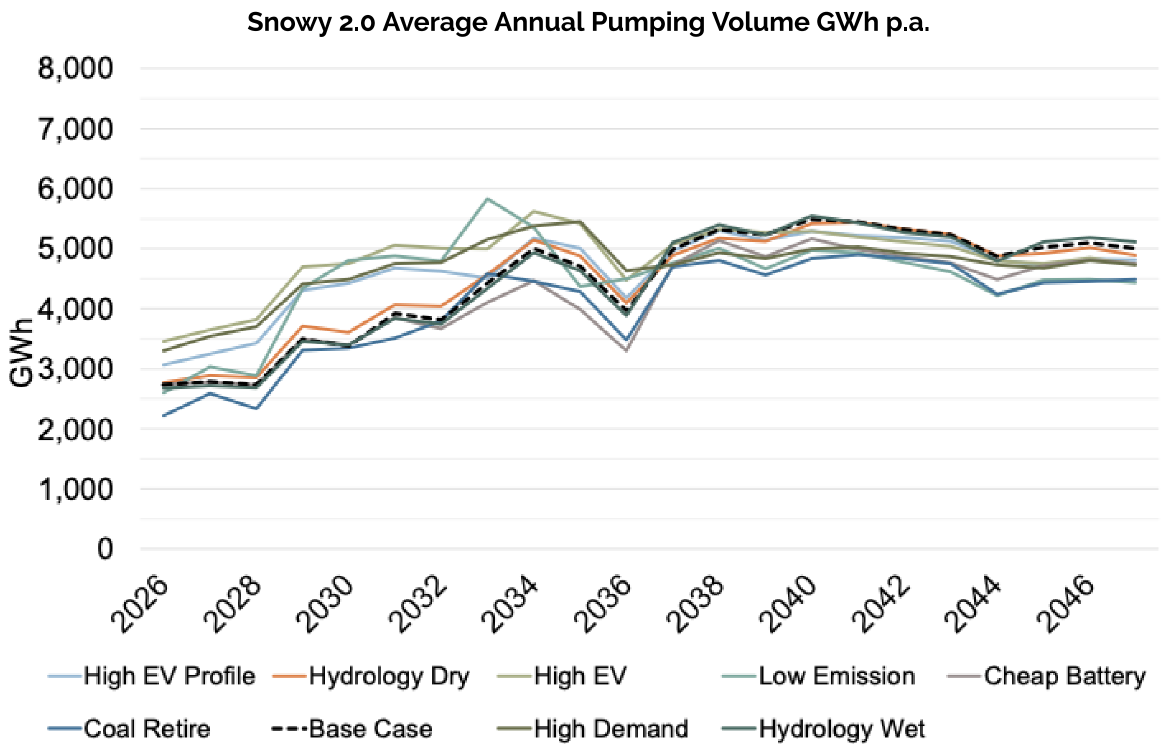


Figure 5: All Scenarios – Pumping Volumes [Source: MJA]

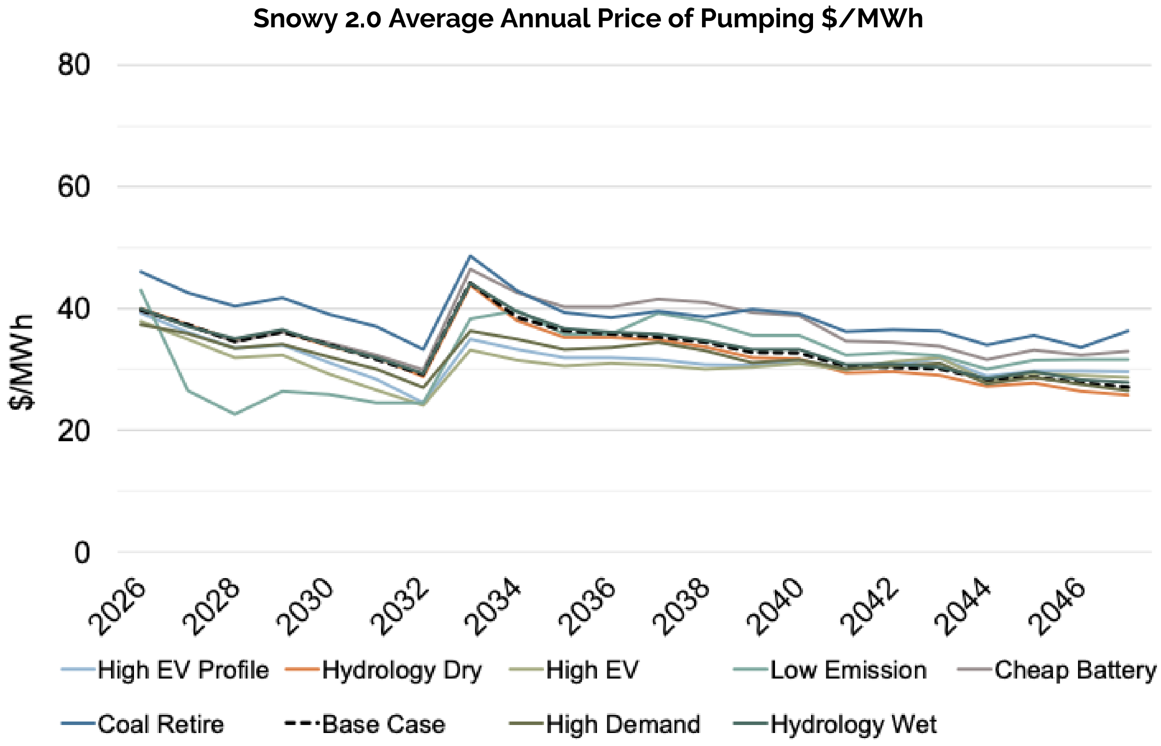


Figure 6: Snowy 2.0 Pumping Prices [Source: MJA]

Case	Assets	Base	Low Carbon	Coal Early Closure	High Demand	Hydrology Wet	Hydrology Dry	High EV Penetration (Flat)	High Battery
Without Snowy 2.0									
	Snowy 1.0	11,213	12,600	13,994	12,581	1,839	10,850	12,179	10,991
With Snowy 2.0									
	Snowy 1.0	10,717	12,473	13,059	11,610	11,318	10,238	11,347	10,612
	Snowy 2.0	4,139	4,948	4,675	4,581	4,097	4,162	4,630	3,776
	Total	14,856	17,421	17,734	16,191	15,415	14,400	15,977	14,389
Change		**3,643**	**4,821**	**3,740**	**3,610**	**3,576**	**3,550**	**3,798**	**3,398**

Table 4: Scenarios and Cases – Net Spot Market Revenue [Source: MJA]

Change from Base	Base	Low Carbon	Coal Early Closure	High Demand	Hydrology Wet	Hydrology Dry	High EV Penetration	High Batter y
2019-2047	2,012	3,050	1,998	1,960	1951	1,906	1,658	1,623
2048-2075	1,631	1,771	1,742	1,650	1624	1,644	1,587	1,775
Total	**3,643**	**4,821**	**3,740**	**3,610**	**3576**	**3,550**	**3,245**	**3,398**

Table 5: Scenarios and Cases – Change in Snowy Hydro Net Spot Market Revenue [Source: MJA]

4.4 Base Case Scenario

Please *see Supporting Chapter Five* for full description.

4.5 Low Emissions Scenario

4.5.1 Overview

This section presents the description of and modelling results for the Low Emissions Scenario. It represents how the NEM, under the assumptions contained in the Base Scenario, would develop if a policy were implemented that required emissions reductions (compared to 2005 level) of 45% by 2030 and 80% by 2050.

The modelling showed that substantial changes (compared to the Base Scenario) were required by 2030 and in the late 2040s.

4.5.2 Description and assumptions

This scenario assumes that a policy of a 45% reduction in emissions by 2030 (calendar year) and an 80% reduction by 2050 is enacted and met in the NEM.

As the mechanism under which this would be implemented can impact spot prices, this needed to be assumed.

The assumptions regarding these issues are described below.

Abatement Strategies

Actions required to satisfy this high abatement scenario included the following:

1. Coal plant operating less (recognising capacity would be required for power system reliability). This can be achieved through temporarily closing coal generator units down (for example on a seasonal basis) or operating units at a lower capacity factor;
2. Early closures of coal plant;
3. Accelerated development of rooftop PV (through appropriate incentives);
4. Increased large-scale VRE development (which will be required to be significantly higher than in the Base Scenario);

5. Required increase in VRE firming (gas generation and storage) to support the increase in VRE; and
6. Basslink II to be developed – due to the increased need for firming together with a policy on emissions abatement.

Coal plant closures

The amount of coal power station reduction required by 2030 was similar to the level of coal plant the Base Scenario had in 2036. This would in effect mean moving forward the coal plant reduction that the Base Scenario had in 2030 to 2029. The coal plant generation profile assumed was as follows:

Closure:

1. Eraring closed over the period 2027/28 to 2028/29;
2. Loy Yang A closed over the period 2044/45 to 2045/46; and
3. Stanwell all units closed on 2046/77.

Seasonal operations (only servicing summer and winter):

1. Half Bayswater from 2015/26 onwards;
2. All Loy Yang B from 2034/35 onwards;
3. Half Millmerran from 2034/35 onwards;
4. Half Callide from 2034/Y35 onwards; and
5. 25% Stanwell from 2034/35 onwards (only in the 'without Snowy 2.0' case).

Large-scale VRE Development

With coal generation at the level of the mid-2030s in 2029, the development of VRE generation was required to be accelerated in order that the installation level in 2029 was similar to that in the Base Scenario in 2035.

The development of VRE to meet the level required in 2029 would need to be undertaken in the years leading up to 2030. This development would occur in the years before the closure of any coal power stations. Post-2030 their need for development would be gone.

Rooftop PV development

Consistent with a 45% emissions reduction policy would be incentives to increase the development of rooftop PV. The 2018 AEMO ESOO only provided a single outlook for rooftop PV development.

It was assumed that incentives would be put in place to accelerate rooftop PV installation. The assumption was that the AEMO rooftop PV development profile was moved forward by 5 years (ie the level of PV installation reached in 2030 was that projected by AEMO to be in 2035).

To meet the 2050 emissions target, post-2030 the development of rooftop PV would need to continue on a accelerated path compared to the Base Scenario.

From a total system generation perspective, the impact of rooftop PV and large-scale PV are very similar but not the same. Rooftop PV is not tracking and consequently has a narrower profile. More kW of rooftop PV is required for the same kWh of output compared to large-scale PV due to the poor orientation of many rooftop PV systems.

Battery installation

The significant firming required would likely have regulation introduced requiring new VRE to have accompanying storage. The amount was assessed in the modelling.

Basslink II

It is assumed that a 600 MW DC interconnector between VIC and Tasmania would be developed (ie Basslink II) and that this would enter in 2028. The basis of this assumption was as follows:

1. The substantial firming capacity that would be required in the NEM;
2. Basslink II offers lower firming costs than batteries;
3. Tasmania can be expected to have over 600 MW of export capacity above the 500 MW on the existing Basslink under most conditions;
4. The July 2018 report by TasNetworks costed a 600 MW link (Option 1) in the indicative range of $1.4–$1.9 billion and a 1,200 MW link (option 2) in the range $1.9–$2.7 billion. The 1,200 MW link would require the development of pumped storage capacity to have the generation to utilise the additional 600 MW capacity available over Option 1. The cost of the pumped hydro in Tasmania is not known; and
5. The earliest Basslink II can enter has been quoted as 6 to 7 years.

Mechanism

The mechanism used to achieve a 45% emissions reduction is relevant to pricing and spot price outcomes. Alternatives to this are policies that have been previously suggested:

1. A price on carbon emissions (ie similar to the Carbon Pollution Reduction Scheme);
2. Emission intensity scheme;
3. Clean Energy Target (recommended in the Finkel Review);
4. NEG-type emissions compliance arrangements; and
5. Government intervention to close coal power stations (an option forwarded in the Finkel review).

The Australian Labour Party have indicated that NEG-type arrangements may be preferred. These arrangements have the obligation on retailers and large energy purchasers to demonstrate that the generation used/contracted to supply their demand satisfies the emission reduction requirement. Low emission generation can be purchased through the trading of NEG emission certificates.

Under this arrangement there would be a penalty for non-compliance, which if based on the level of non-compliance would have a monetary value proportional to the total emissions exceeded. This lends itself to a $/tonne compliance cost. Compliance costs do not add to the spot price.

Under a scenario of high emissions abatement (such as a 45% reduction by 2030) there may be required a quantum of gas generation being dispatched over coal generation. Under a carbon price this would result from the emissions cost increasing the SRMC of coal above the SRMC of gas. The dynamic is different than under the emissions type arrangements as proposed under the NEG, as there are no costs directly associated with emissions in the pool (ie all generator SRMCs remain unchanged).

Early closure of one of more coal power stations would be part of an optimum strategy to achieve the low emissions. Such an outcome may be beyond what could be achieved through a NEG type arrangement and would require direct government intervention/incentive.

Given a mix of coal plant and gas generation required to replace coal generation (to lower emissions), there would be a requirement for gas generation to offer a dispatch price under that of coal generation. Under this scenario:

1. The emissions contract would pay gas generation SRMC + capital for its generation. The contract would require actual generation;
2. Gas generation would bid under coal generation;
3. Coal generation would clear the market more often. With its bids unchanged it would receive a lower spot price (equal to what its increase in SRMC would have been under a carbon price);
4. Renewable generation receives lower revenue than in the no emissions abatement scenario;
5. There is a substantial contract premium provided to the gas generation plant. This is not hedging spot price but paying for actual generation to reduce emissions;
6. The economics of coal generation would require this generation to shadow gas generation, as has been observed in the NEM since the closure of Hazelwood Power Station. This would be assisted by the knowledge that gas generation would be operating under coal generation for a proportion of the time. This would mean clearing prices are largely unchanged;
7. There is likely to be some residual generation that bids to maintain peak prices near new entry levels; and
8. Price spread for storage plant would potentially reflect significant excess coal generation and high prices when either coal or gas was clearing the market.

4.5.3 Low Emissions Scenario – NEM Outcomes

Figure 7 below shows a selection of the modelling results from the Low Emissions Scenario. Shown are:

1. The NSW average annual spot prices;
2. Daily average NSW spot prices for 2019, 2028, 2038, 2047;
3. For the 'with Snowy 2.0' case, the change in moving from the Base Scenario to the Low Emissions Scenario (ie positive if the Low Emissions Scenario is higher);
4. The change in moving from the 'without Snowy 2.0' case to the 'with Snowy 2.0' case (ie positive if the 'with Snowy 2.0' case is higher);
5. For the 'with Snowy 2.0' and 'without Snowy 2.0' cases, the NEM carbon emissions; and

6. Snowy 2.0 generation and pumping volumes and average pumping and generation prices.

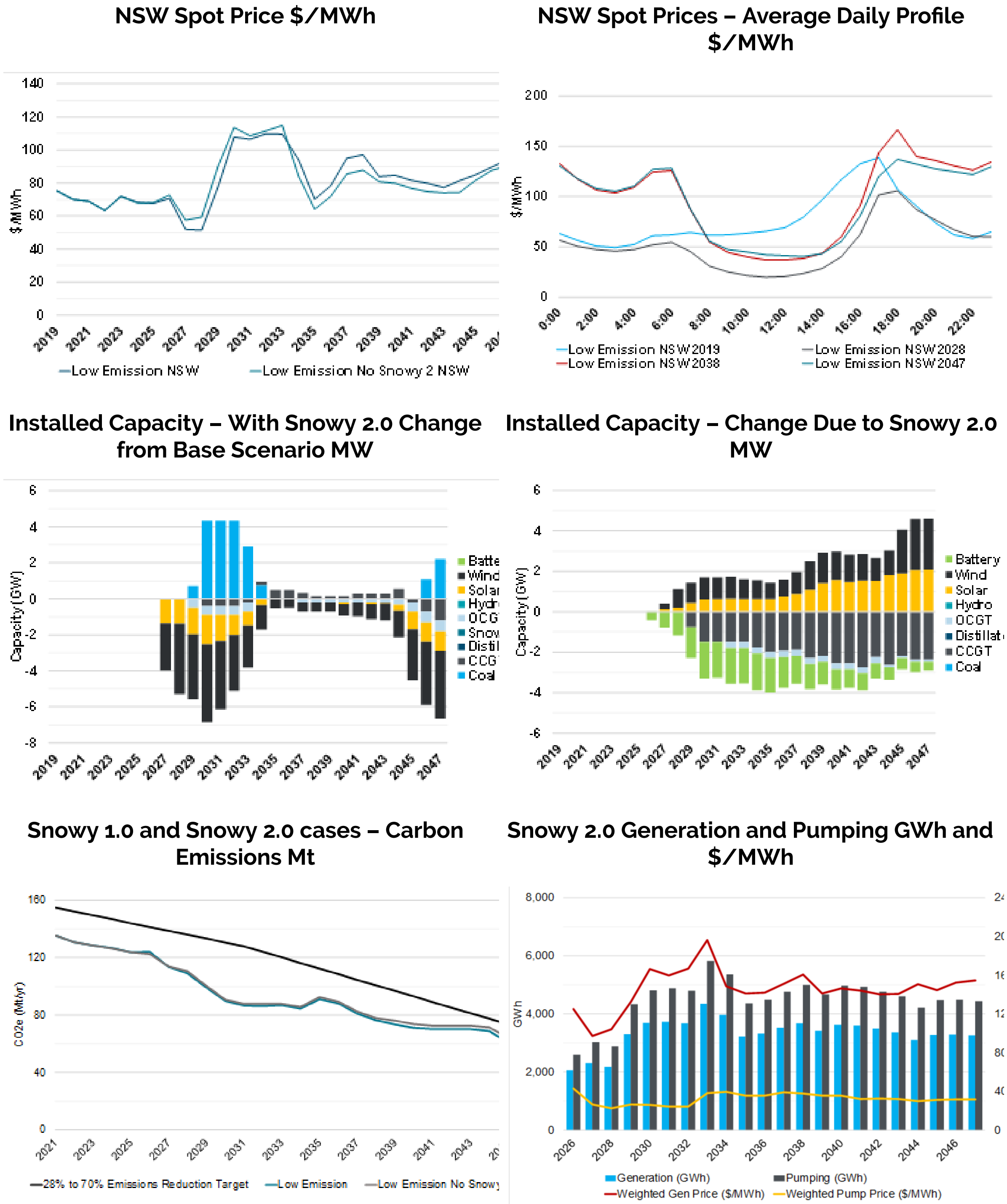


Figure 7: Low Emissions Scenario – NEM Outcomes - Modelling Results [Source: MJA]

The following observations are made.

Spot Prices

Spot prices decrease in the late 2020s as additional VRE is developed to the level required to be operating in 2030. The closure of coal plant over the period 2027 to

2029 results in a significant increase in spot prices, reflecting less capacity and increasing gas generation clearing the market.

There is volatility in spot prices as the market trends to where the Base Scenario was in 2035, reflecting increased sensitivity of spot prices to the bidding of dispatchable capacity.

By 2037 spot prices are slightly higher than the Base Scenario.

Installed generation and storage capacity

The profile of generation installation reflects the market having accelerated development such that by 2029 the installed capacity is similar to what the Base Scenario was in 2035, noting that the Low Emissions Scenario has a higher level of rooftop PV development and Basslink II developed.

Carbon emissions

The changes provide for the level of carbon emissions in 2030 (calendar year) to be near the 45% reduction (compared to 2005 levels). The profile has:

1. A fast reduction in emissions in the late 2020s to satisfy the 2030 target;
2. Post-2030 the profile of emissions flattens out (as the market returns to near where it was in the Base Scenario); and
3. Action is taken in the late 2040s to address the 2050 emissions target. This has emissions dive down to reach that target through the closure of coal power stations.

4.5.4 Low Emissions Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Figure 8 shows the annual net spot market revenues for the Snowy 1.0 and Snowy 2.0 cases. This is compared to the Base Scenario through colours on the bars:

1. The light brown is the Base Scenario;
2. The blue is the case being plotted (ie Low Emissions scenario here); and
3. The dark brown is the overlap of the two cases.

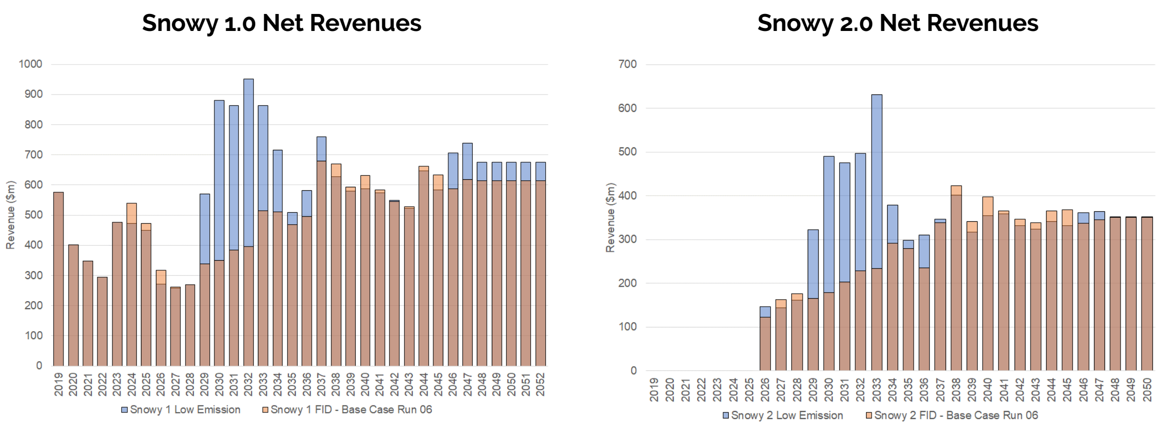


Figure 8: Low Emissions Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues [Source: MJA]

The change in revenues is evident from the high spot prices associated with the large changes that occur in the late 2020s.

More interesting are the changes in the mid-2040s as Loy Yang is retired earlier in order for emissions to meet the 2050 target. The closure of coal plant results in additional gas plant and some storage. This results in buy and sell prices increasing.

Table 6 below presents the NPV profitability (revenues minus operating costs) for the 'without Snowy 2.0' and 'with Snowy 2.0' cases.

Case	Assets	Period		
		2019 – 2047	2047– 2075	Total
No Snowy 2.0				
	Snowy 1.0	10,034	2,566	12,600
With Snowy 2.0				
	Snowy 1.0	9,646	2,827	12,473
	Snowy 2.0	3,438	1,511	4,948
	Total	13,084	4,337	17,421
Change due to Snowy 2.0		3,050	1,771	4,821

Table 6: High Demand Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

4.6 Early Coal Closure Scenario

Some of the existing coal power stations could close earlier than has been assumed in the Base Scenario. This could arise from policy changes or from economics associated with aging assets. The implications of coal closing earlier are complex as it involves the response to replacing the firm capacity and the energy production foregone.

4.6.1 Description and assumptions

One of the recommendations of the Finkel Review was the early closing of coal power stations. A potential policy was limiting their operating life to 50 years.[8]

This was the assumption of the Early Coal Closure Scenario. On this basis all existing coal plant was retired after 50 years. Table 7 presents the dates when the existing coal power stations reach 50 years of age.

[8] (Finkel et al. 2017). Page 175 reads: 'The Lifetime limits on coal-fired generators: A lifetime limit would require coal-fired generators to close once they reach a certain age. The lifetime limit would be approximately consistent with the expected investment life of the generation asset. A lifetime limit of 50 years was modelled as a scenario for this Review.'

	No of Units	Unit Size MW MW	Commissioning Start	Finish	Age Years	Year when 50 Years Old
Queensland						
Tarong	4	350	1984	1986	32	2036
Tarong Nth	1	450		2003	15	2053
Stanwell	4	350		1996	22	2046
Callide C	2	420		2001	17	2051
Callide B	2	350		1988	30	2038
Millmerran	2	450		2002	16	2052
Kogan Creek	1	750		2007	11	2057
Gladstone	6	280		1976	42	2026
New South Wales						
Eraring	4	720	1982	1984	34	2034
Vales Point	2	660	1978	1979	39	2029
Mt Piper	2	700	1992	1993	25	2043
Bayswater	4	660	1985	1986	32	2036
Liddell	4	500	1971	1973	45	2023
Victoria						
Loy Lang A	4	550	1984	1988	30	2038
Loy Yang B	2	483	1993	1996	22	2046
Yallourn	2	350				
	2	375	1972	1974	44	2024

Table 7: Early Coal Power Station Closure [Source: MJA]

The coal plants that would retire earlier than in the Base Scenario were as follows:

1. Gladstone would close in 2026 (rather than the Base Scenario assumption of 2029);
2. Loy Yang A would close in 2038 (rather than the Base Scenario assumption of 2048); and
3. Loy Yang B would close in 2046 (rather than the Base Scenario assumption of 2056).

The consequences of this are:

1. The period 2034 to 2038 would have Eraring, Tarong, Bayswater, Callide B, Loy Lang A closed, a total of 9,820 MW of base load generation. This would require gas and storage generation to provide at least this much capacity together with a substantial amount of additional VRE generation;
2. With Liddell and Vales Point power stations having closed prior to 2030, NSW would only have 700 MW of coal generation (Mt Piper) after 2036;
3. The closure of Loy Yang A in 2038 alone, a base load power station that operates at high capacity factor, would have a very significant impact, both in terms of capacity and energy to be replaced; and
4. All coal generation in VIC would have exited by 2046.

The absence of an emissions limit in this scenario would provide for gas plant to be developed. However, such development may have substantial risks:

1. Gas supply is uncertain, both in terms of availability and price. A significant increase in Gas Power Generation (***GPG***) development would likely be reflected in increased gas prices (for term supply) and also the requirement for a substantial investment in gas pipelines; and
2. Given that the early coal closure policy is based on a policy of emissions reduction, gas plant would have a risk associated with potential future emissions policy.

For the purposes of this scenario it was assumed that gas generation with gas supply would be available at the costs assumed in the base case. It would be likely that gas cost would be higher due to an increase in gas demand.

The substantial firming requirements also provide for Basslink II to be developed under the same assumptions as in the Low Emissions Scenario.

4.6.2 Early Coal Closure Scenario – NEM Outcomes

Figure 9 shows a selection of the modelling results from the Early Coal Closure Scenario. This is the standard set that is used in all the scenarios (and that was described in the Base Scenario).

The following observations are made:

Spot prices

The impact of closing large base load assets is higher spot prices. On the basis that the replacement generation would be VRE and gas generation (as was the output of the modelling), the replacement plant would need to enter service over years prior to the coal power station closure. This would reduce spot prices and act to reduce the difference between this and the Base Scenario.

Upon closure spot prices would increase. Higher spot prices tend to be more elastic to change in capacity such as that associated with Snowy 2.0.

Installed generation and storage capacity

The installed generation and capacity would reflect the change to spot prices associated with the closed coal generators. Without a signal to reduce emissions a large component of this would be gas generation.

In practice there may be a significant risk associated with the development of new gas generation:

1. Gas generation may be required to be curtailed in the future if stringent emissions limits were introduced post-development of the gas generation; and
2. The availability and cost of gas could be uncertain.

If these risks reduced the development of gas generation and additional VRE and storage were required, this would increase the value of Snowy 2.0 storage.

Carbon Emissions

Closing coal generation necessarily reduces carbon emissions. However, locking in substantial amounts of gas generation may result in a long-term emissions issue which would have been lower as a result of VRE having a longer development time and improved economics due to its reducing cost curve.

Snowy 2.0 generation and pumping

Closing coal generation and replacing with gas generation reduces the availability of pumping energy. This results in a lower level of Snowy 2.0 generation.

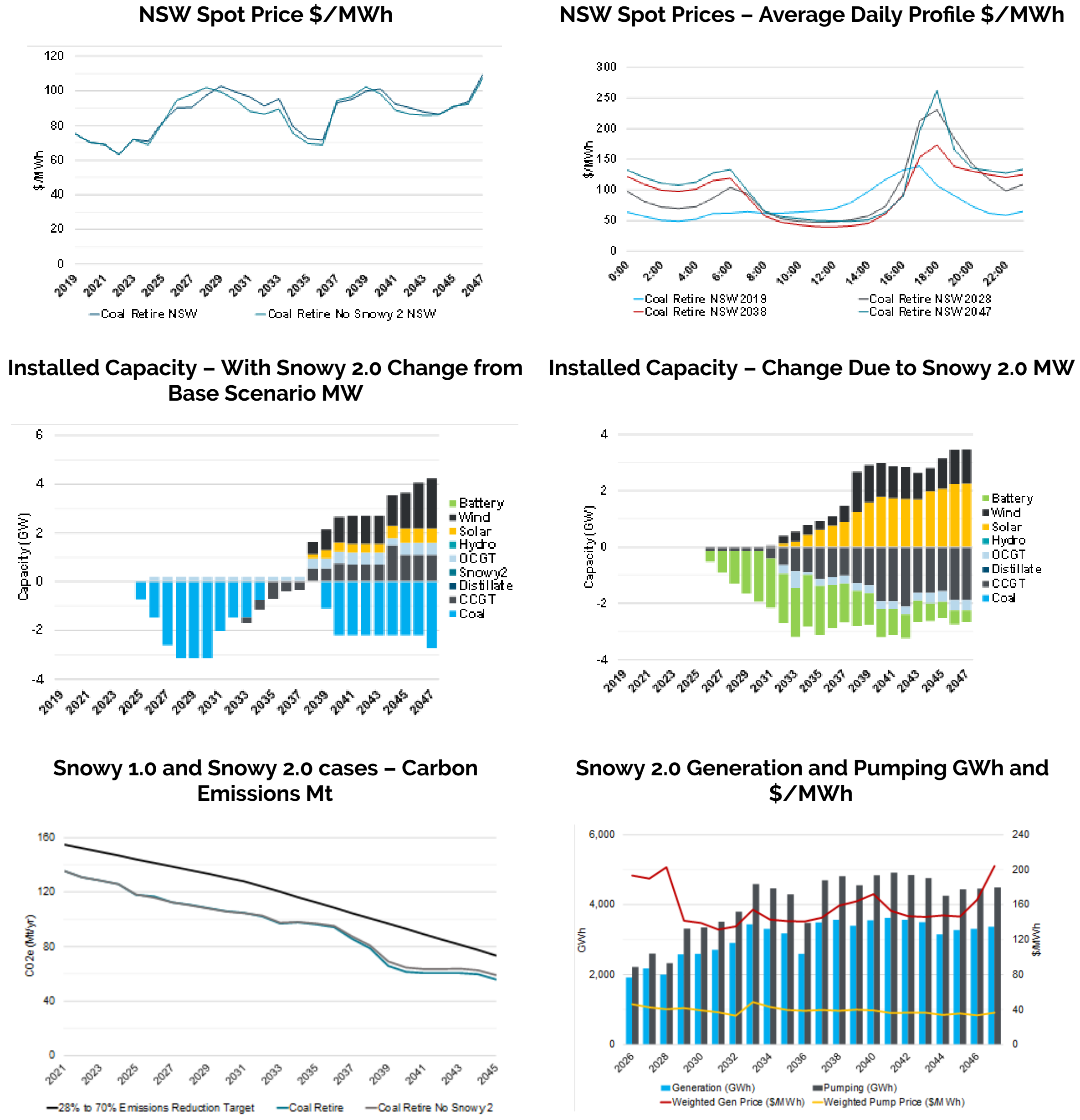


Figure 9: Early Coal Closure Scenario – NEM Outcomes - Modelling Results [Source: MJA]

4.6.3 Early Coal Closure Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Figure 10 below shows the annual net spot market revenues for Snowy 1.0 and Snowy 2.0 cases. The colours show the comparison to the Base Scenario:

1. The light brown is the Base Scenario;
2. The blue is the case being plotted (ie Low Emissions scenario here); and
3. The dark brown is the overlap of the two cases.

Table 8 below presents the NPV profitability (revenues minus operating costs) for the 'without Snowy 2.0' and 'with Snowy 2.0' cases. As observed, closing coal power stations increases net revenues to Snowy 1.0 and Snowy 2.0. There are years when Snowy 2.0 net revenues are less due to lower pumping energy.

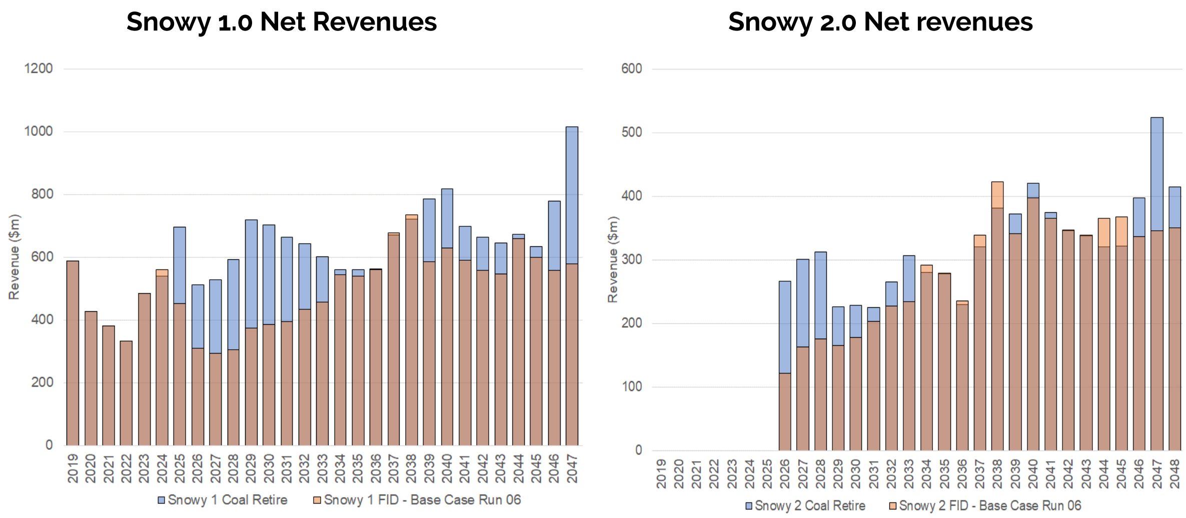


Figure 10: Early Coal Closure Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues [Source: MJA]

Case	Assets	Period		
		2019-2047	2047-2075	Total
No Snowy 2.0				
	Snowy 1.0	11,121	2,873	13,994
With Snowy 2.0				
	Snowy 1.0	10,045	3,014	13,059
	Snowy 2.0	3,074	1,601	4,675
	Total	13,118	4,615	17,734
Change due to Snowy 2.0		1,998	1,742	3,740

Table 8: Early Coal Closure Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

4.7 High Demand Scenario

A higher level of demand growth would require additional new generation than under the Base Scenario, which would require both energy production and dispatchable capacity. This would increase spot prices and bring forward the time that the 2,000 MW of Snowy 2.0 capacity would be required in the market. It would also lead to a different balance of VRE, thermal generation and storage.

4.7.1 Description and assumptions

The 2018 AEMO demand projections contained three load growth scenarios, namely Neutral, Fast and Slow. The Fast Scenario represented a higher demand outlook.

In comparison to the Neutral scenario, AEMO state the following regarding the Fast scenario:[9]

> ...projected stronger growth in new dwellings and more rapid forecast uptake of electric vehicles, residential annual delivered consumption NEM-wide is forecast to go up by half over the 20-year forecast (or 2.5% annual average).
>
> ...earlier increase in electricity usage than the Neutral scenario, as it assumed Liquefied Natural Gas (***LNG***) companies will be more aggressive in debottlenecking LNG facilities, resulting in more Coal Seam Gas (***CSG***) being produced to fill LNG trains. In the longer term, the Fast change scenario considers the possibility of an additional LNG export facility from 2025, ramping up to full capacity export by 2027 and sustained for the remaining forecast period 55. While there is no current prospect for future LNG facilities, this increase serves in the modelling as a proxy for new electricity-intensive load in QLD. It does not reflect any known investment under consideration.'

This scenario assumed the 2018 AEMO Fast Scenario demand projection. The demand increases over the period in terms of NEM energy and regional NEM maximum demands corresponds to that shown in Table 9 below.

	Energy Increase GWh	Maximum Demand Increase MW
2030	20,000	3,000
2040	30,000	5,000
2050	40,000	7,000

Table 9: High Demand Scenario Description [Source: MJA]

In the same manner as the Base Scenario, increased demand had generation facilities respond through the most economic options. Coal plant was not an option due to the risk issues previously presented.

4.7.2 High Demand Scenario – NEM Outcomes

Figure 11 below shows a selection of the modelling results from the High Demand Scenario. This is the standard set that is used in all the scenarios (and that was described in the Base Scenario).

[9] (AEMO 2018).

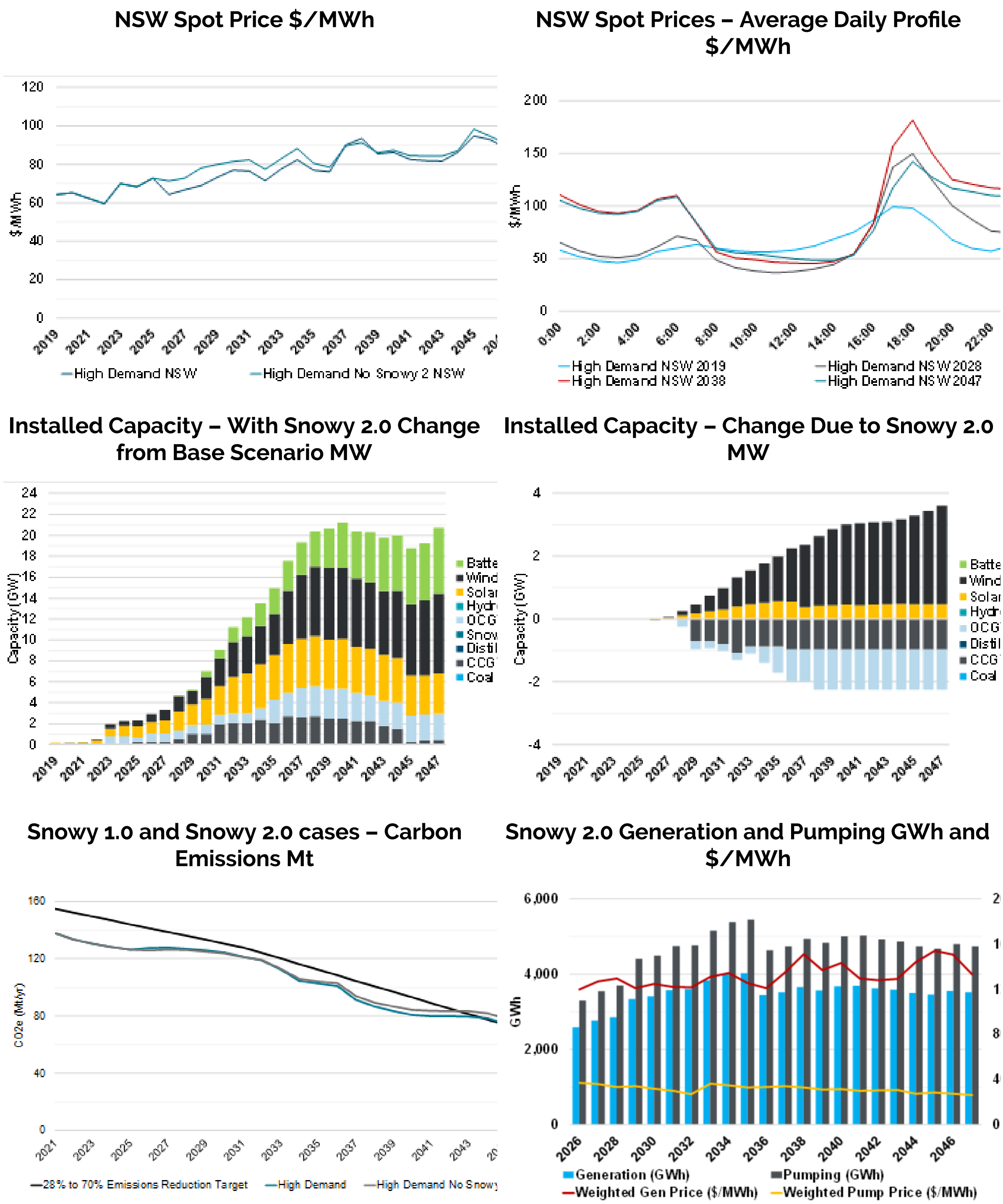


Figure 11: High Demand Scenario – NEM Outcomes - Modelling Results [Source: MJA 19/10/18]

The following observations are made:

Spot prices

The profile of spot prices has the same general trend as the Base Scenario with the change that it is slightly higher and the price decreases due to Snowy 2.0 lasting longer. This can be understood as follows:

1. Higher demand levels increase the price sensitivity of spot prices to change in supply; and
2. Higher demand and prices resulted in an increase in the amount of new generation entering, both gas generation and VRE.

The shape of the daily price profile is the same as the Base Scenario (as would be expected) but the price spread between the sample years over the daytime period 9 am to 4 pm is slightly wider than in the Base Scenario, and the evening peak is maximum in 2028 and then decreases. This indicates a complex dynamic associated with the factors influencing prices: coal generator, storage and gas generator offer prices.

Installed Generation and storage capacity

The High Demand outlook results in substantial additional investment in gas generation (CCGT and OCGT) and VRE:

1. By 2030 the additional investment is about 1,700 MW in gas generation and 5,000 MW in VRE; and
2. By 2040 the additional investment is about 5,000 MW in gas generation and 12,000 MW in VRE, which provides the firm capacity (gas generation and storage) and energy required to satisfy the increased demand.

Carbon Emissions

The higher demand level without an emission limit results in emissions being higher than the Base Scenario. Snowy 2.0, as in the Base Scenario, results in lower emissions through providing for more VRE to economically operate in the NEM.

Snowy 2.0 generation and pumping

The level of generation reduces from 2036 compared to the base case after the closure of Bayswater. This is due to the reduction of pumping energy due to high demands resulting in a reduction in spot prices suitable for pumping.

4.7.3 High Demand Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Figure 12 below shows the annual net spot market revenues for the Snowy 1.0 and Snowy 2.0 cases. The colours show the comparison to the Base Scenario as previously described.[10]

Table 10 below presents the NPV profitability (revenues minus operating costs) for the 'without Snowy 2.0' and 'with Snowy 2.0' cases.

Observations from Figure 12 include:

1. Higher demand increases the revenues of Snowy 1.0 (as would be expected) due to higher spot prices; and

[10] The colours show the comparison to the Base Scenario:
- The light brown is the Base Scenario;
- The blue is the case being plotted (ie Low Emissions scenario here);
- The dark brown is the overlap of the two cases.

2. Snowy 2.0 revenues increase due to higher selling prices except for the period 2037 to 2043. This is due to coal plant closures requiring gas to be marginal more often and reducing time available for pumping.

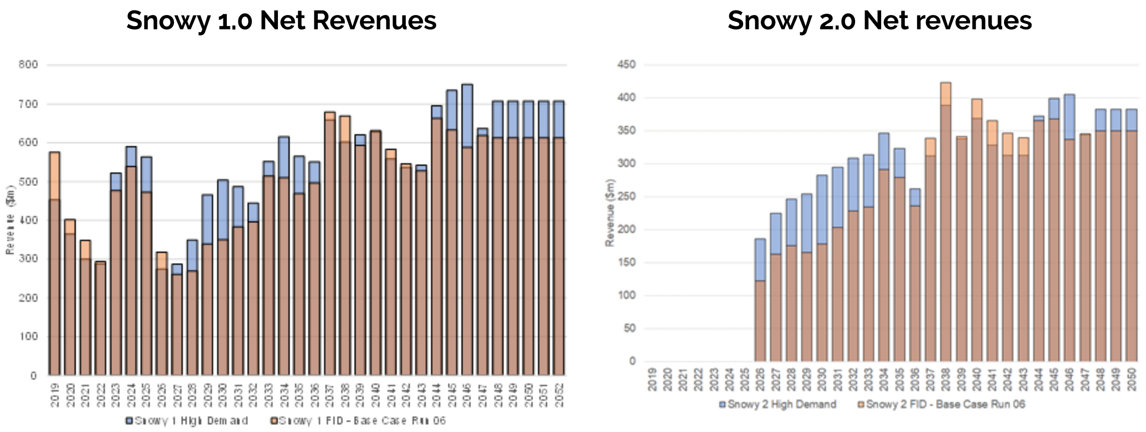


Figure 12: High Demand Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues [Source: MJA 19/10/18]

Case	Assets	Period		
		2019-2047	2048-2075	Total
No Snowy 2.0				
	Snowy 1.0	9,835	2,746	12,581
With Snowy 2.0				
	Snowy 1.0	8,769	2,842	11,610
	Snowy 2.0	3,027	1,554	4,581
	Total	11,795	4,396	16,191
Change due to Snowy 2.0		1,960	1,650	3,610

Table 10: High Demand Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA 19/10/18]

4.8 Hydrology Wet Scenario

4.8.1 Overview

Hydropower station available generation is subject to variability of water inflows. Weather variability results in drought and wet years and while potentially long are non-permanent, whereas climate shifts may have average inflows change. It may not be possible to separate the two causes to changes in inflows.

A hydrology wet scenario has increased water inflows to all hydro plants. This does not impact Snowy 2.0 generation availability which is determined by the availability of pumping energy. It may decrease the relative value of Snowy 2.0 by having more generation competition in the market.

4.8.2 Description and assumptions

General

This scenario represents an outlook of continued wet conditions (ie compared to that assumed in the Base Scenario) from 2025. These conditions increase the generation available to all hydropower stations (in the NEM) including Snowy 1.0 by an assumed 10% (through the increased inflow of water for generation).

Table 11 shows the average hydro generation from the two major hydro schemes in the NEM plus the other smaller schemes. The hydropower stations in TAS (owned and operated by Hydro Tasmania) represent about 66% of the total hydropower generated (GWh) in the NEM. Snowy 1.0 represents about 26% and the remainder less than 10%.

Hydro Scheme	Average Annual Generation GWh p.a.	Generation Increase GWh p.a.	Increase in peak period Generation MW[11]
Snowy 1.0	4,000	400	91
Hydro Tasmania	10,000	1,000	228
Other Hydro[12]	1,000	100	23
Total	15,000	1,500	342

Table 11: Increase in Annual Hydro Generation due to Wet Conditions [Source: MJA]

Hydro Tasmania

The market impact will depend on how this additional hydro generation is used. Excluding Snowy 1.0, Hydro Tasmania comprises about 90% of hydro generation in the NEM.

The use of hydro generation from Tasmania is reflected in Basslink flows, which represent the difference between generation in Tasmania (hydro plus wind and possibly gas) and Tasmanian demand. Currently Tasmania imports about 700 to 1,000 GWh pa from VIC (and an amount equal to about 7 to 10% of Tasmanian annual demand).[13]

Hydro Tasmania dispatches hydro generation based on hydro condition, requirements of Tasmanian security, Tasmanian spot prices, and the value of arbitrage trading across Basslink (this is selling to VIC when Victorian spot prices are high and buying from VIC when Victorian spot prices are low).

Figure 13 below illustrates the concept of water value for hydro generators in the context of Tasmanian hydro and flows across Basslink. The key point is that in the absence of hydro constraints, additional water captures a value equal to the minimum price it was previously willing to sell.

[11] This assumes hydro only operates during the top 50% of demand times.
[12] Estimated.
[13](Project Marinus 2018) Section 2.2: 'Based on long-term average inflows, however, Tasmania has a deficit of on-island generation compared to consumption of approximately 700 GWh to 1,000 GWh per annum (approximately 7 per cent to 10 per cent). As a consequence, Tasmania imports a small portion of its electricity from VIC via Basslink to meet its energy needs.'

Figure 13 shows for the 2017-18 year the historical Victorian spot price duration curve and Basslink flows (corresponding to the Victorian spot price). As observed, there are flows across Basslink in both directions at all Victorian spot prices (except for very high Victorian prices). This illustrates that trading across Basslink (buy and sell) arbitrages Victorian spot price differences over periods over a day.

This meant that additional generation to Hydro Tasmania would operate across all Basslink flows.

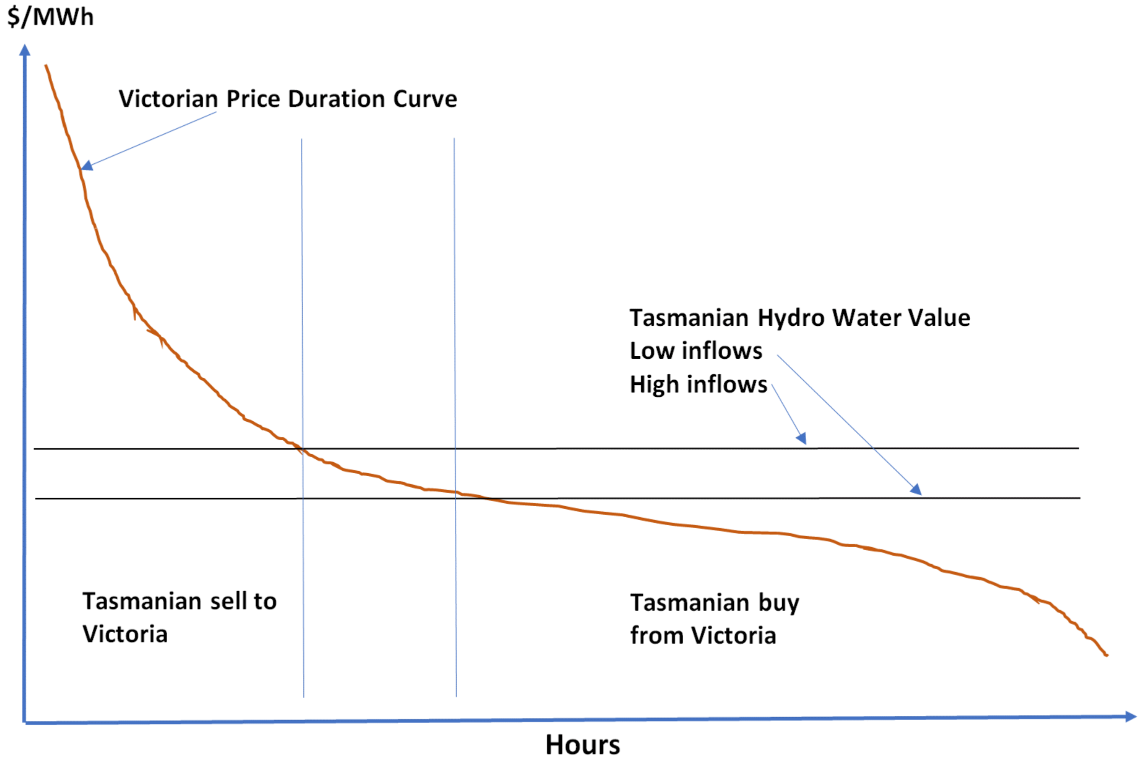


Figure 13: Theoretical Basis – Value of Additional Water to Hydro Tasmania [Source: MJA]

Theoretically, Hydro Tasmania develops a value for (marginal) water based on minimising the cost of energy purchased from VIC.

An increase in water inflows to Tasmanian hydro would result in additional sales to VIC at the marginal value of water. There would not be additional sales at high prices as these sales opportunities would have already been taken.

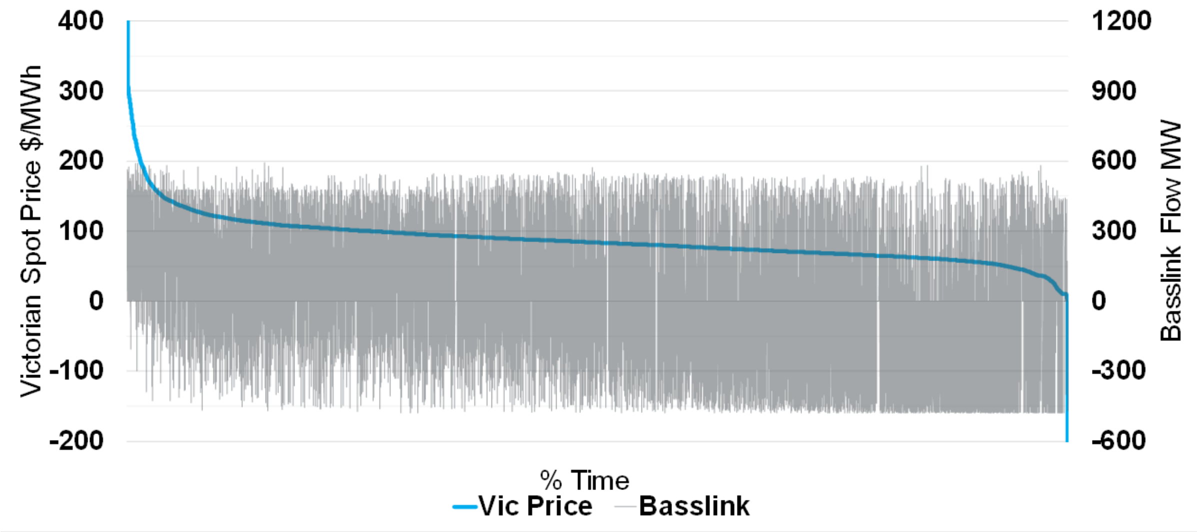


Figure 14: 2017-18 – Victorian Spot Price Duration Curve and Basslink Flows [Source: MJA]

Snowy 1.0

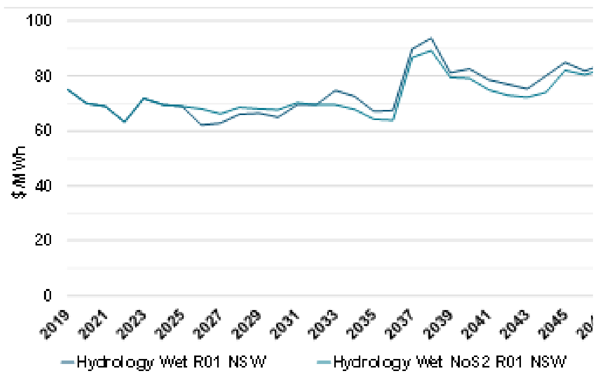
The additional water to Snowy 1.0 would provide for Snowy 1.0 to increase generation.

This would reduce some of the high value operating hours that would have been captured exclusively (within Snowy Hydro) by Snowy 2.0. The net impact would be an expected increase in Snowy Hydro enterprise value and a small reduction in the value difference between Snowy 1.0 and Snowy 1.0 plus Snowy 2.0.

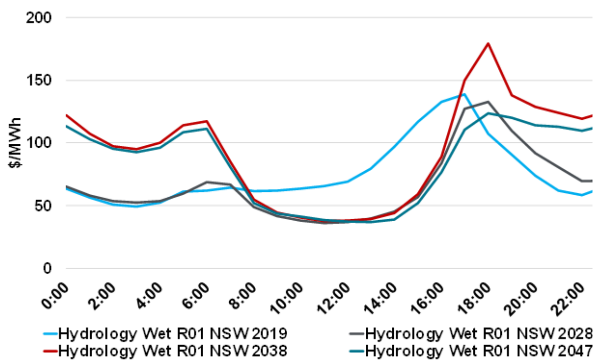
4.8.3 Hydrology Wet Scenario – NEM Outcomes

Figure 15 below shows a selection of the modelling results from the Hydrology Wet Scenario. This is the standard set that is used in all the scenarios (and that was described in the Base Scenario).

NSW Spot Price $/MWh



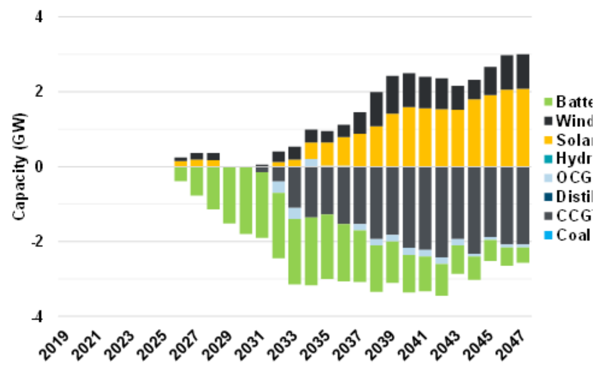
NSW Spot Prices – Average Daily Profile $/MWh



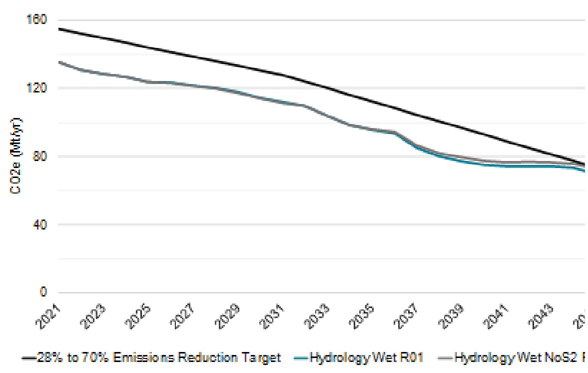
Installed Capacity – With Snowy 2.0 Change from Base Scenario MW

No Change from Base Scenario

Installed Capacity – Change Due to Snowy 2.0 MW



Snowy 1.0 and Snowy 2.0 cases – Carbon Emissions Mt



Snowy 2.0 Generation and Pumping GWh and $/MWh

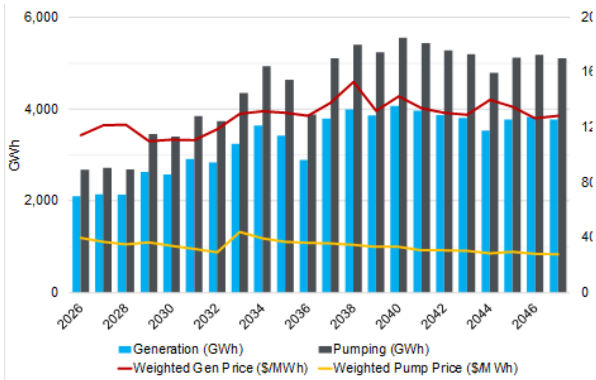


Figure 15: Hydrology Wet Scenario – NEM Outcomes - Modelling Results [Source: MJA]

The following observations are made:

Spot prices

Spot prices reflect the additional generation from all the NEM hydropower stations. The additional generation is predominantly not supporting contracts and acts to reduce spot prices.

Installed generation and storage capacity

There is no change in installed capacity. This reflects the uncertain nature of this additional energy and that it is mainly used during times when spot prices reflect the value of water (ie at the lowest value times of hydro generation).

Carbon emissions

Additional generation from renewable generation (with no emissions) reduces emissions.

Snowy 2.0 generation and pumping

Additional hydro generation provides increased competition to Snowy 2.0 generation and does not provide additional pumping energy.

4.8.4 Hydrology Wet Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Figure 16 below shown the annual net spot market revenues for Snowy 1.0 and Snowy 2.0 cases. As in the previous scenarios presented the colours show the comparison to the Base Scenario.[14]

The increased generation provides for additional revenues to Snowy 1.0, and Snowy 2.0 is marginally lower.

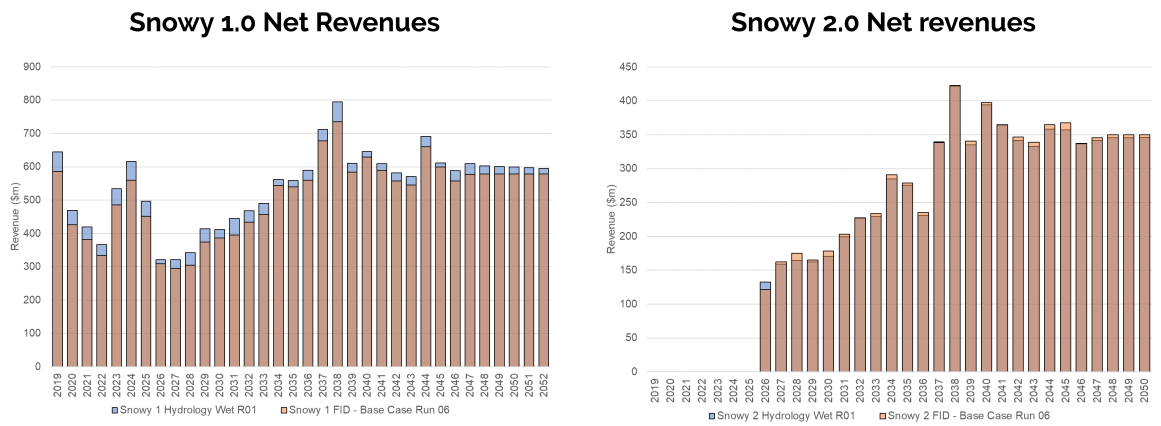


Figure 16: Hydrology Wet Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues [Source: MJA]

Table 12 below presents the NPV profitability (revenues minus operating costs) for the 'without Snowy 2.0' and 'with Snowy 2.0' cases.

[14] The colours show the comparison to the Base Scenario:

1. The light brown is the Base Scenario;
2. The blue is the case being plotted (ie Low Emissions scenario here); and
3. The dark brown is the overlap of the two cases.

Case	Assets	Period		
		2019-2047	2048-2075	Total
No Snowy 2.0				
	Snowy 1.0	9,262	2,577	11,839
With Snowy 2.0				
	Snowy 1.0	8,617	2,701	11,318
	Snowy 2.0	2,596	1,501	4,097
	Total	11,213	4,201	15,415
Change due to Snowy 2.0		1,951	1,624	3,576

Table 12: Hydrology Wet Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

4.9 Hydrology Dry Scenario

4.9.1 Overview

A hydrological dry scenario would reduce Snowy 1.0 generation level (and other hydro generators). The ability of Snowy 2.0 to increase generation through increased pumping provides a natural 'hedge' to Snowy 1.0 and the NEM against such circumstances.

A drought (dry conditions over say three years) may have hydro generation decrease significantly providing greater value to Snowy 2.0 ability to increase generation when required. A permanent reduction in inflows would have a different dynamic. This scenario considers a permanent reduction in NEM hydro water inflows.

4.9.2 Description and assumptions

This scenario represents an outlook of continued dry conditions (ie compared to that assumed in the Base Scenario) from 2025. These conditions decrease the generation available to all hydropower stations including Snowy 1.0 by an assumed 10% (through a decrease in the inflow of water for generation).

This is the opposite of the Hydrology Wet Scenario described in the previous section. The issues are the same with the exception that generation levels are assumed to be reduced.

A Hydrology Dry Scenario would decrease the Snowy Hydro enterprise value but would be expected to increase the value difference between Snowy 1.0 and Snowy 1.0 plus Snowy 2.0.

The long-term climate outlook is that Australia will become dryer and thus hydro yields will decrease.

4.9.3 Hydrology Dry Scenario – NEM Outcomes

Figure 17 below shows a selection of the modelling results from the Hydrology Dry Scenario. These are the standard set that are used in all the scenarios (and that were described in the Base Scenario).

The following observations are made:

1. While the dry scenario had Snowy 1.0 generate less, it also had all other hydro in the NEM generate less;
2. The reduction in Snowy 1.0 generation is at those hours of least value, this is at the 'water value' (which may vary through each year). The better this value is correctly assessed at the start of a year (which involves projecting both hydro yield and spot price outcomes) the lower the impact of a reduction in hydro generation would be;
3. The reduction in Hydro Tasmania generation, which involves Tasmania net importing a larger amount of energy, should also involve an increase in the Tasmanian water value and changed generation when spot prices are near this value. However, a historical review of Basslink flows suggests that the change in Basslink flows might occur over the entire Victorian price curve;
4. The net impact to Snowy 1.0 is a value loss through lower generation and a value gain through slightly higher spot prices;
5. The continuous reduction in hydro production means that the market would settle at a new balance and Snowy 2.0 would not be used to 'hedge' Snowy Hydro during a temporary period (say several years) where Snowy 1.0 generation is substantially lower.

The net result of the modelling has Snowy Hydro not greatly impacted.

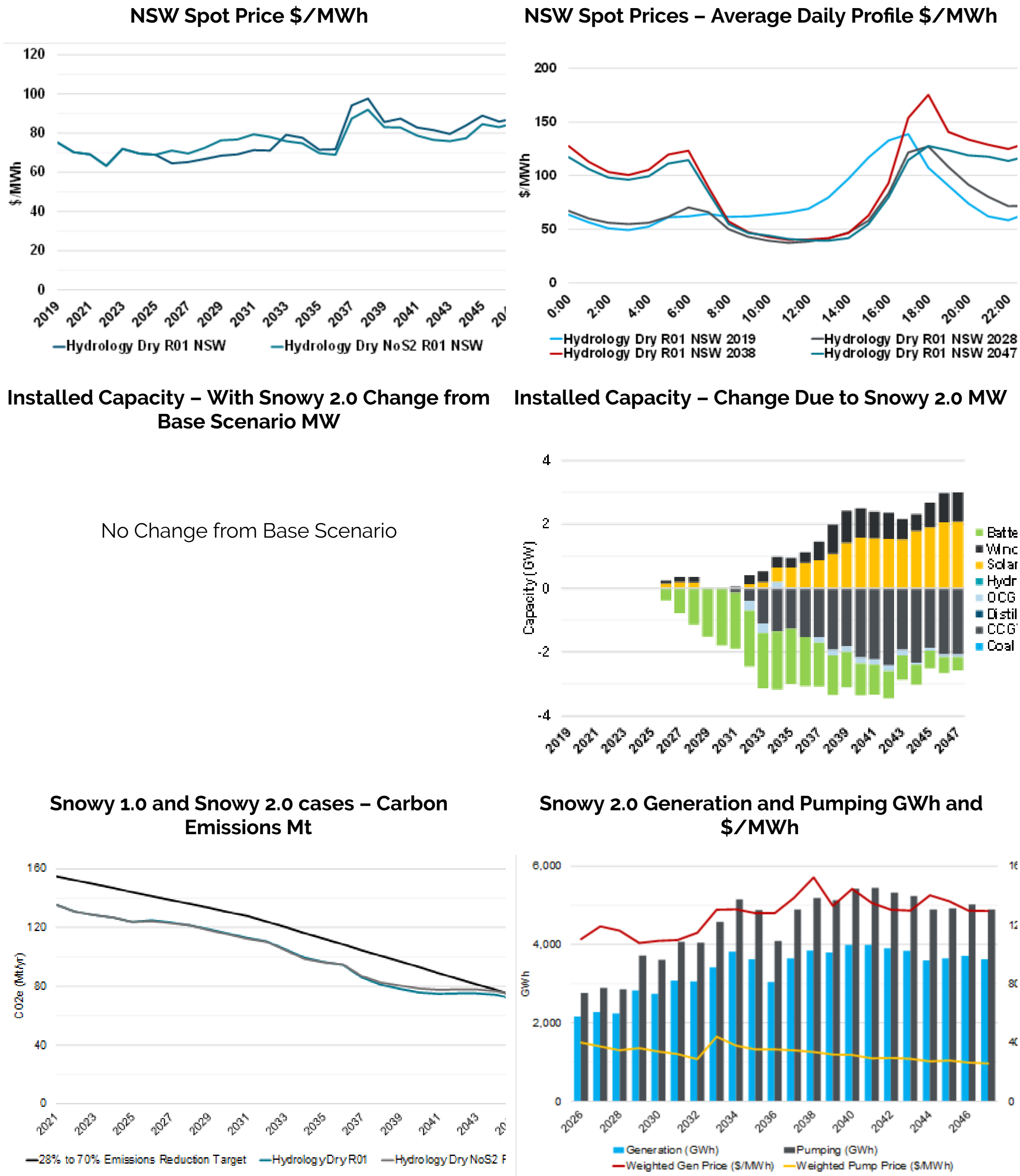


Figure 17: Hydrology Dry Scenario – NEM Outcomes - Modelling Results [Source: MJA]

4.9.4 Hydrology Dry Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Figure 18 below shows the annual net spot market revenues for Snowy 1.0 and Snowy 2.0 cases. As in the previous scenarios presented the colours show the comparison to the Base Scenario.[15]

[15] The colours show the comparison to the Base Scenario:

1. The light brown is the Base Scenario;

Snowy 1.0 revenues vary between higher and lower indicating the complexity of the impact on spot prices and Snowy 1.0 generation pattern. The long term, which has the NEM near balance, has Snowy 1.0 revenues lower. Snowy 2.0 generally has slightly higher net revenues.

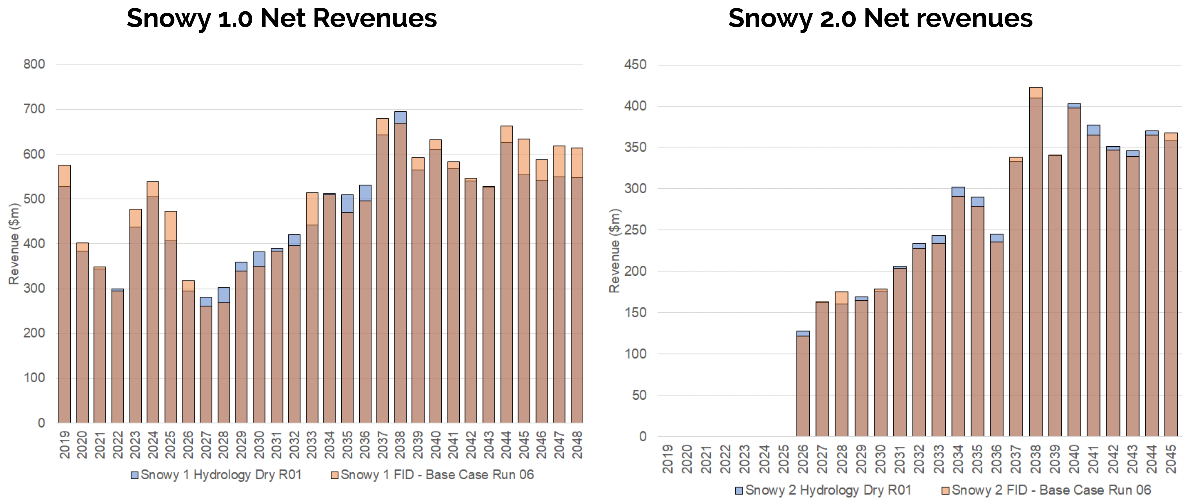


Figure 18: Hydrology Dry Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues [Source: MJA]

Table 13 below presents the NPV profitability (revenues minus operating costs) for the 'without Snowy 2.0' and 'with Snowy 2.0' cases.

Case	Assets	Period		
		2019-2047	2048-2075	Total
No Snowy 2.0				
	Snowy 1.0	8,363	2,487	10,850
With Snowy 2.0				
	Snowy 1.0	7,615	2,623	10,238
	Snowy 2.0	2,654	1,508	4,162
	Total	10,269	4,131	14,400
Change due to Snowy 2.0		1,906	1,644	3,550

Table 13: Hydrology Dry Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

4.10 High EV Scenario

The rapid development of EVs would result in an increase to demand with a profile reflecting charging times, and connected batteries to the grid which may have potential to be used centrally.

The most significant impact would be the amount of energy required and the profile of charging. The profile is unknown.

2. The blue is the case being plotted (ie Low Emissions scenario here); and
3. The dark brown is the overlap of the two cases

If this uptake is substantial, the impact to demand and the profile of demand has the potential to significantly impact storage operation and value. This scenario entailed modelling a very high uptake and this was done assuming two different charging profiles.

4.10.1 Description and assumptions

This scenario represents a policy to have 80% of cars on the road as EVs by 2040.

The implications of this are:

1. A significant increase in electricity demand from the grid;
2. A profile which may have higher demand in low price periods; and
3. A significant increase in batteries connected to the grid (when charging).

These matters are addressed below.

Increase in energy demand

Figure 19 below presents the profile of annual EV electricity demand for the Base Scenario, 50% EVs on road by 2050, and 80% of EVs on road by 2040.

The increase in energy demand resulting from a trajectory of 80% EVs on road by 2040 is substantial - the basis of this demand level is presented in *Modelling Snowy 2.0 in the NEM Appendices (MJA)*. By 2032 the increase over the base scenario is about 20,000 GWh, representing over 10% of total NEM demand and equivalent to a 3,000 MW base load power station.

EV charging demand profile

There is very little information on the likely charging profile of EVs. This profile will be influenced by:

1. The time to charge a car – fast charging rates would require a significant increase in the capacity of the transmission grid; and
2. The times available to charge – overnight for cars used during the day and continuously for cars parked at residences.

To address this unknown, two profiles were modelled. The names of these scenarios were:

1. High EV Flat Increase Scenario - This had the demand increase as a flat level across each day representing continuous charging of cars; and
2. High EV Profiled Increase Scenario - The profile used is shown in Figure 20 below. This had charging during lower demand lower spot price periods.

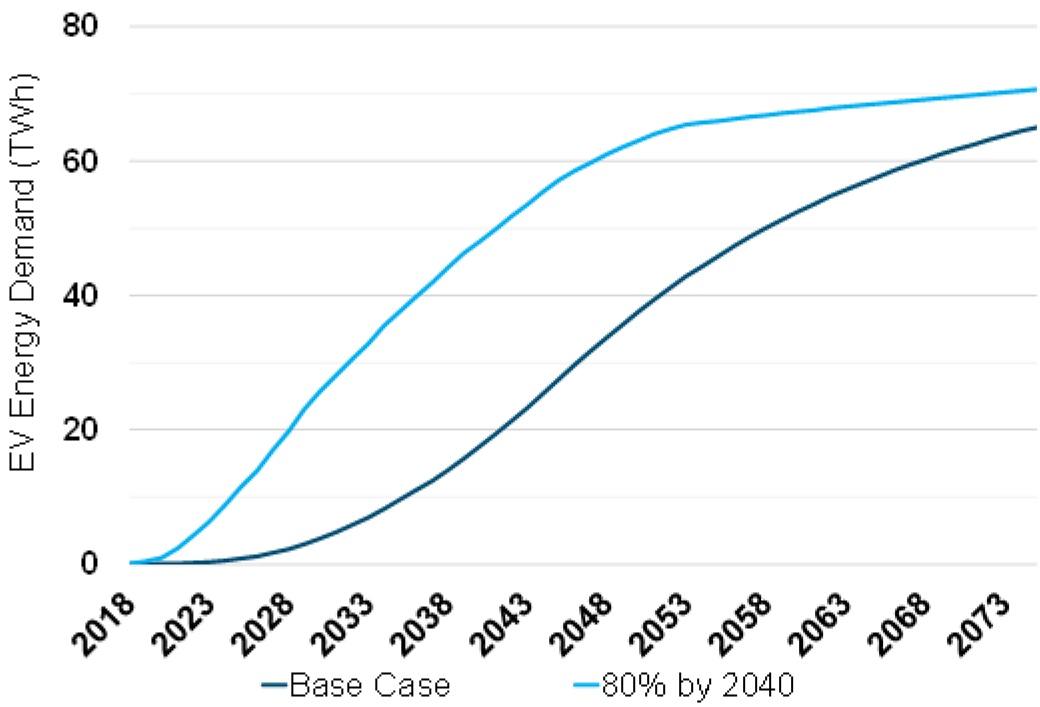


Figure 19: EV Development Profiles and Energy Requirement [Source: MJA]

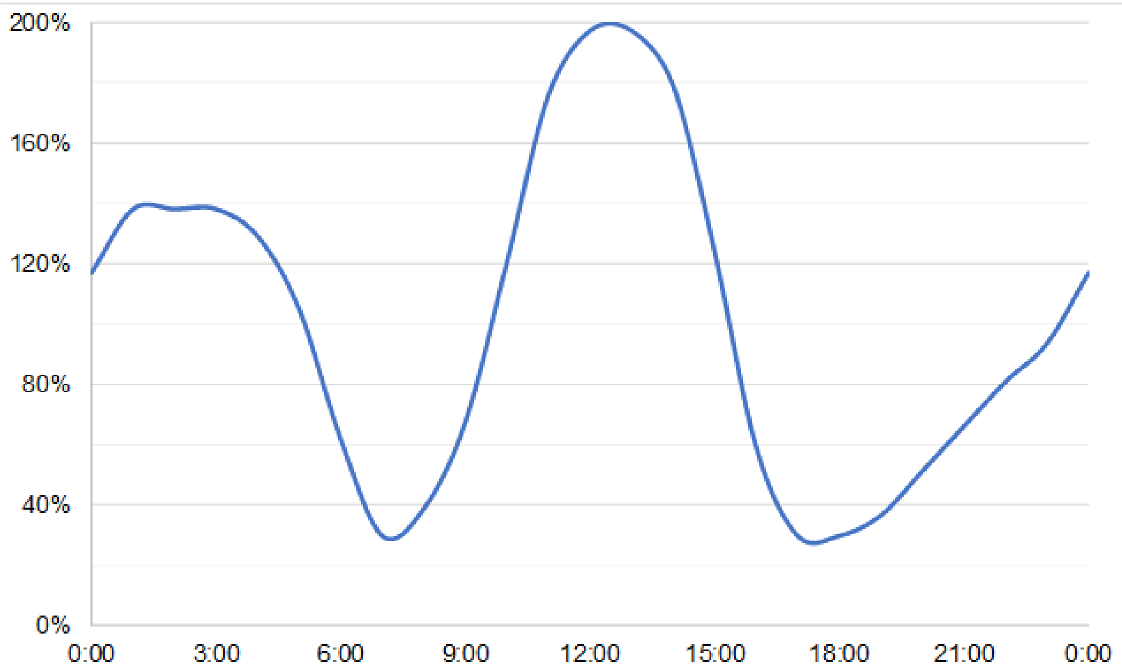


Figure 20: High EV Profiled Increase Scenario – EV Demand Profile [Source: MJA]

Use of batteries

Evidence to date suggests that batteries from EV will not behave in an 'aggregated manner' (meaning control handed over to AEMO for system management purposes) but will more closely follow a 'convenience' profile.

With increased penetration of residential solar PV, the likely reduction in solar feed-in tariffs, and the use of 'smart' technology to optimise charging we expect that households will look to use their own 'free' solar generation to charge their vehicle where possible. This will have a two-fold benefit of reducing EV charging from the grid as well as reducing the 'duck curve' effect on the aggregate demand profile caused by lower residential demand as a result of increased solar PV generation. We also expect that retailers will look to use tariffs and other incentives to smooth demand resulting from EV charging.

However, there is also likely to be the availability by the market operator to utilise battery capacity through controls to stop charging for limited periods. This would provide capacity value and would reduce the development of firm capacity such as OCGT gas plant and battery capacity.

4.10.2 High EV Scenarios – NEM Outcomes

This section presents the NEM outcomes for the two high EV scenarios modelled. The results of the modelling of these two cases are presented in turn below.

High EV Flat Increase

Figure 21 below shows a selection of the modelling results from the High EV Flat Increase Scenario. This is the standard set that is used in all the scenarios (and that was described in the Base Scenario).

The key changes in spot prices compared to the Base Scenario are as follows:

1. Spot prices are generally higher;
2. The 2037 increase in spot prices in lower; and
3. Spot prices increase to high levels post-2045.

The reasons for these changes have been assessed as follows:

1. The increased demand results in higher spot prices;
2. Additional generation enters which reduces the sensitivity of spot prices to the closure of coal generation; and
3. The higher demand results in a greater amount of gas generation and this clears the market more often, particularly post-2045.

Snowy 2.0 generation and pumping

The standard graphs showing Snowy 2.0 pumping and generation volumes and prices are given below. The most notable changes from the Base Scenario are that pumping and generation volumes are slightly lower post-2040 compared to the Base Scenario. The dynamic is complex. The changes are assessed as due to more gas generation and a lower quantity of low priced generation for pumping.

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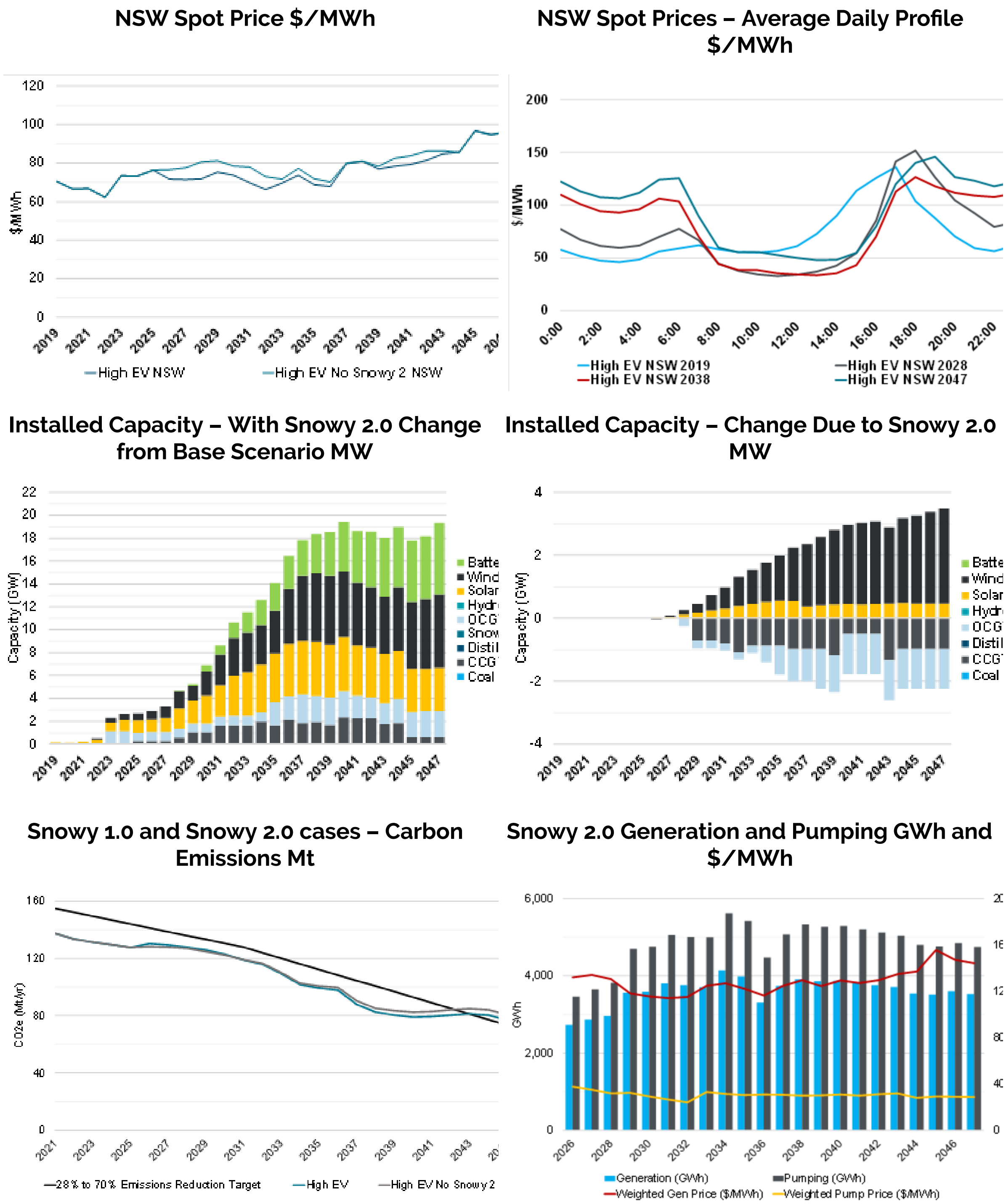


Figure 21: High EV Flat Increase Scenario – NEM Modelling Outcomes [Source: MJA]

The results show that the increase in demand has resulted in the change in VRE due to Snowy 2.0. This had Snowy 2.0 bringing in more wind generation compared to the Base Scenario where Snowy 2.0 brought in more solar generation.

This change highlights the sensitivity and uncertainty in both the amount and type of VRE that Snowy 2.0 would impact and how market conditions can influence this.

Carbon emissions

As would be expected, the increased demand has resulted in an increase in carbon emissions. The intensity of the increase reflects the type of generation that responded to the increase, which has a lower intensity than that of the average pool.

High EV Profiled Increase

Figure 22 below shows the results that changed from the High EV Flat Increase Scenario for the High EV Profiled Increase Scenario.

Shown are:

1. The NSW average annual spot prices; and
2. Snowy 2.0 generation and pumping volumes and average pumping and generation prices.

The changes due to a profiled demand rather than flat are as follows:

1. The increase in spot prices is lower. This reflects a lower increase in the level of maximum demand. This acts to reduce the price level at which pumping is economic; and
2. Snowy 2.0 pumping and generation volumes are slightly lower. This reflects a reduction in spare VRE due to increased demand at times of low prices.

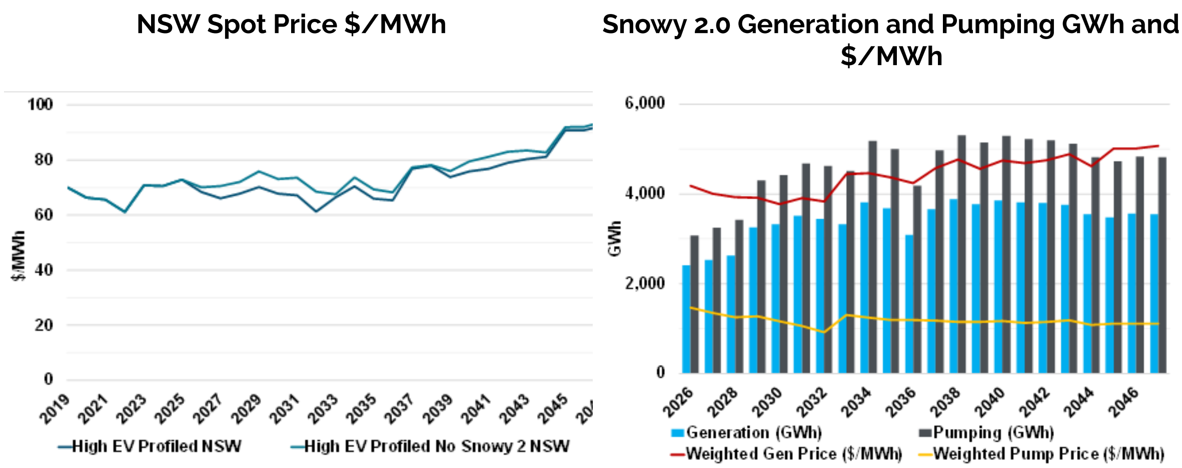


Figure 22: High EV Profiled Increase Scenario - NEM Modelling Outcomes [Source: MJA]

4.10.3 High EV Scenarios – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues

Annual Net Spot Market Revenues

Figure 23 and Figure 24 below show the annual net spot market revenues for Snowy 1.0 and Snowy 2.0 cases for the two high EV scenarios modelled. This is compared to the Base Scenario via colours as above.[16]

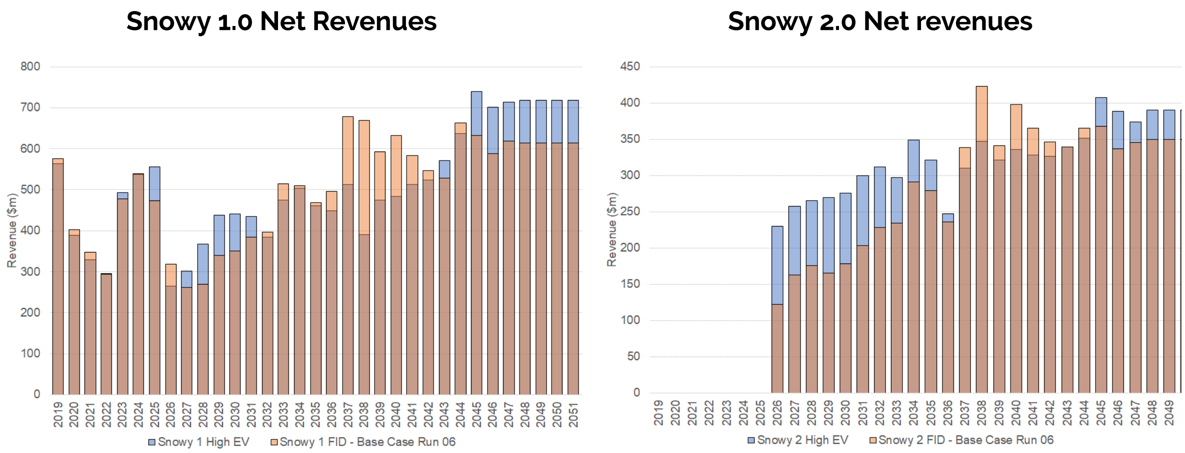


Figure 23: High EV Flat Increase Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Revenues [Source: MJA]

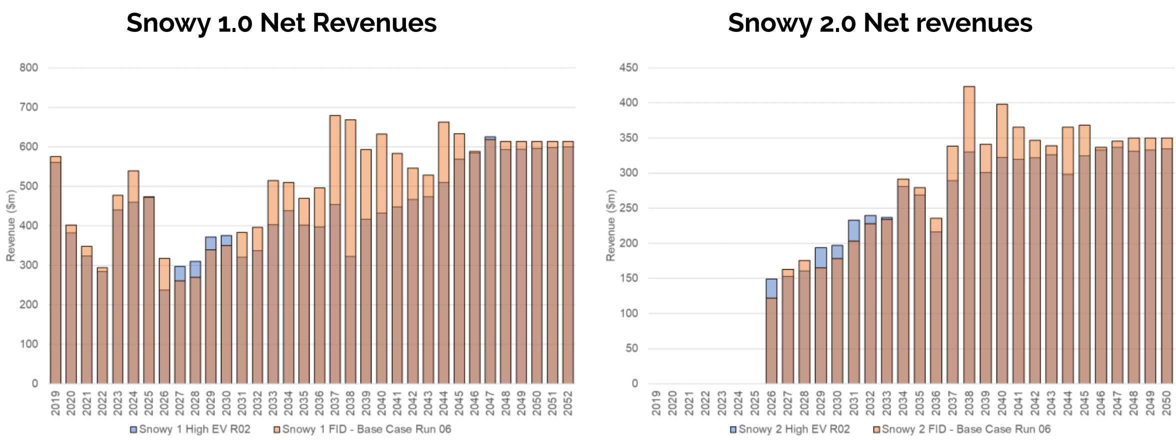


Figure 24: High EV Profiles Increase Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Revenues [Source: MJA]

NPV - Net Spot Market Revenues

The tables below present the NPV of net spot market revenues for the two High EV scenarios modelled.

[16] The colours show the comparison to the Base Scenario:

1. The light brown is the Base Scenario;
2. The blue is the case being plotted (ie Low Emissions scenario here);
3. The dark brown is the overlap of the two cases.

Case	Assets	Period		
		2019-2047	2048-2075	Total
No Snowy 2.0				
	Snowy 1.0	9,492	2,687	12,179
With Snowy 2.0				
	Snowy 1.0	8,490	2,857	11,347
	Snowy 2.0	3,065	1,565	4,630
	Total	11,555	4,422	15,977
Change due to Snowy 2.0		2,063	1,735	3,798

Table 14: High EV Flat Increase Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

Case	Assets	Period		
		2019-2047	2048-2075	Total
No Snowy 2.0				
	Snowy 1.0	8,415	2,594	11,009
With Snowy 2.0				
	Snowy 1.0	7,578	2,701	10,279
	Snowy 2.0	2,495	1,480	3,975
	Total	10,074	4,181	14,254
Change due to Snowy 2.0		1,658	1,587	3,245

Table 15: High EV Profiled Increase Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

4.11 High Battery Scenario

The most direct competitor to Snowy 2.0 is presumably other storage. This competition is both in terms of capacity and hours of storage. While the cost outlook for batteries has them unlikely to be economic on spot market revenues with storage hours over 4 hours, they may enter through regulatory requirements with VRE or other requirements. This scenario models a significant increase in battery development. The impact on revenues is limited to spot market outcomes.

4.11.1 Description and assumptions

The scenario examines the potential consequences of battery costs being significantly lower than that assumed in the Base Scenario. The assumptions of this scenario are as follows:

1. Battery costs reduce at twice the rate assumed in the Base scenario. The resulting battery cost curve is shown in Figure 25 below;
2. Batteries enter when economic, and arbitrage the spot market (this was also the assumption in the Base scenario); and

3. There is no change to new entrant generators (VRE or gas) associated with increased battery development. This was done to illustrate the impact of additional batteries.

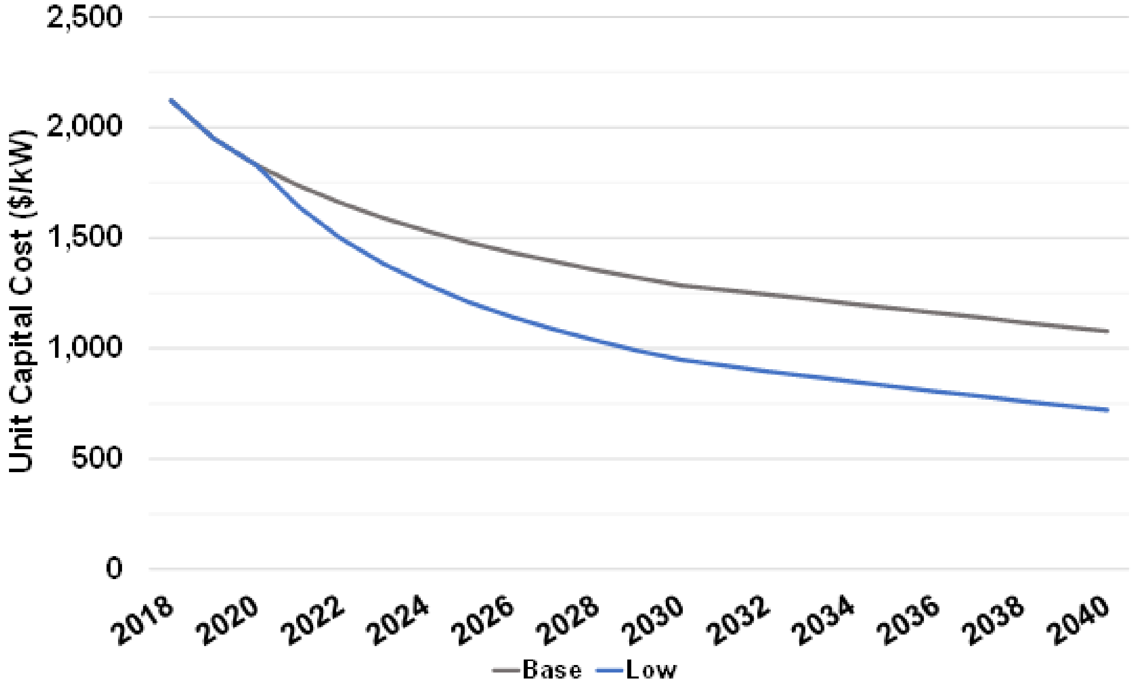


Figure 25: Battery Costs – Base and Low Cost Scenario $/MW (4-hour storage) [Source: MJA]

Battery module costs comprise about 45% of total installation costs. This means that in percentage terms, total battery cost reductions are less than the percentage decrease in battery module costs.

Reduction in Installed Battery Costs

Battery costs are composed of connection costs (to the grid), inverter costs, and the battery module costs. Connection costs are not projected to decrease in real terms, inverter costs slightly and battery module costs significantly.

Battery module costs comprise about 60% of total installation costs. This means that in percentage terms, total battery cost reductions are less than the percentage decrease in battery module costs.

Basis of Battery Entry

The Base Scenario had batteries introduced on the basis that they were required to assist the smoothing of VRE generation that was entering as coal plant closed. These batteries were not economic on spot market revenues (energy arbitrage and Frequency Control Ancillary Services (***FCAS***)). Their entry reflected the requirements of energy purchases and a likely regulatory requirement to have a limited amount of storage accompany VRE development.

The reduction in costs is unlikely to have a level of battery storage development exceed the battery storage assessed as required in the Base Scenario until late in the study period. However, the lower costs of battery storage may result in a potential regulatory requirement increasing the level of batteries to accompany VRE.

Firming costs of VRE would be reduced by the availability of lower cost batteries, and this would assist in the economics of new VRE generation. Increased batteries installation would likely be accompanied by increased VRE development (although this may not be large).

Noting these uncertainties this scenario assumed the following:

1. The additional Battery development (from that in the base Scenario) was close to 4,000 MW by 2041;
2. Individual traders were operating their respective batteries individually (ie they were not subject to central control); and
3. There were no other changes such as additional VRE entry. This assumption was made in order that the impact of additional batteries alone would be observed.

4.11.2 High Battery Scenario – NEM Outcomes

As a first comment, the modelling observed the challenge in coordinating multiple battery operation. This recognised that batteries will be located in different regions and like generators will be managed by parties that may have different projections (over each day) of spot prices and required bids and offers. They may be operated to assist in specific VRE production smoothing and high spot price risk management. A different outcome would likely be obtained if batteries were subject to central control.

The modelling for this scenario was based on the individual traders operating their respective batteries.

Figure 26 below shows a selection of the modelling results from the High Battery Scenario. These are the standard set that are used in all the scenarios (and that were described in the Base Scenario).

The following observations are made:

Spot prices

The profile of spot prices reflected the increased buying at low price times and selling at high price times. The impact was moderate, although better coordination of battery operation could increase this impact.

Installed generation and storage capacity

There was no change assumed for this scenario.

Carbon emissions

Very little change as no new VRE was assumed to entry. Emissions reduced slightly reflecting surplus VRE that was not captured by the storage in the Base Scenario.

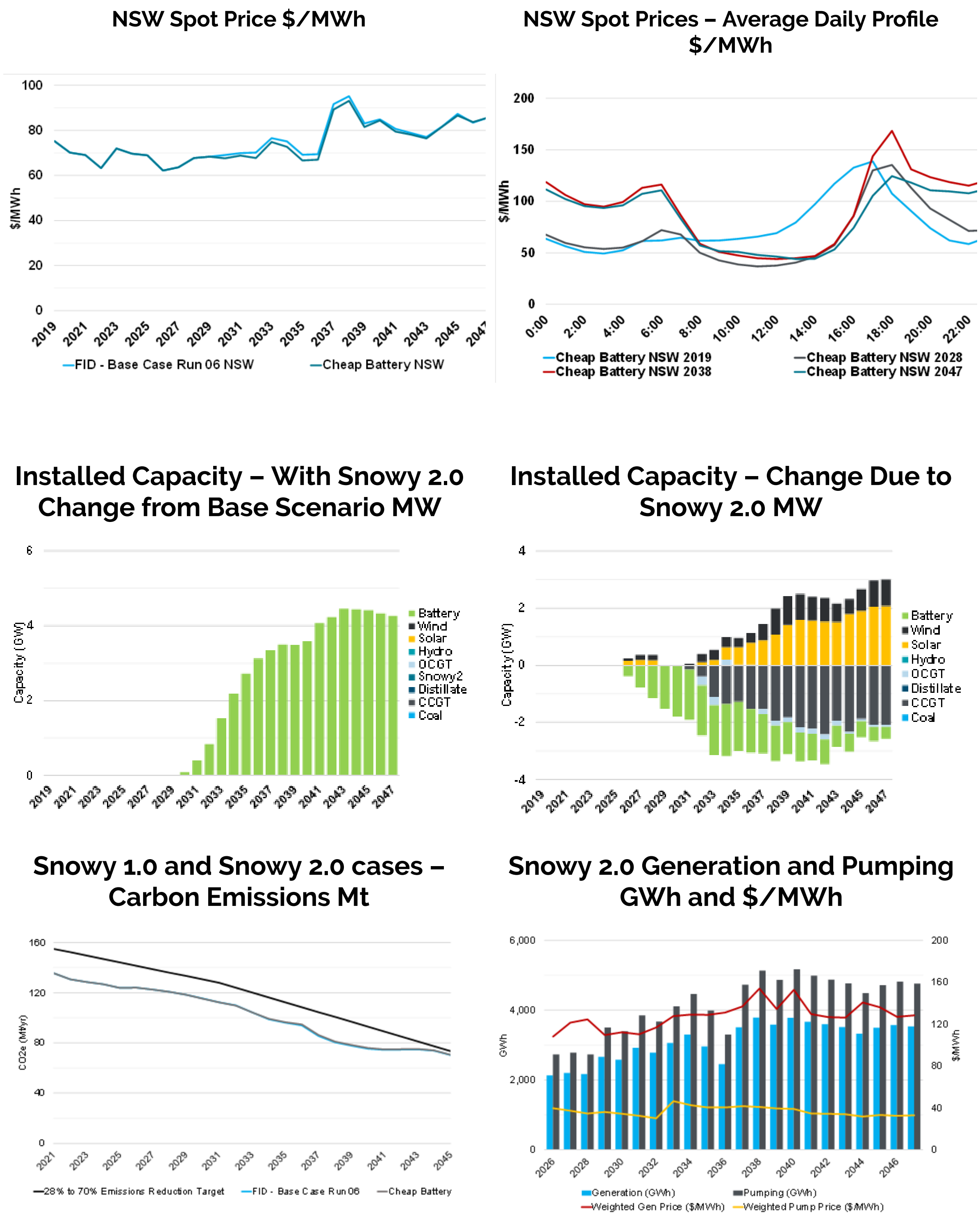


Figure 26: High Battery – NEM Outcomes - Modelling Results [Source: MJA]

4.11.3 High Battery Scenario – S1,0 and Snowy 2.0 Net Spot Market Revenues

Figure 27 below shown the annual net spot market revenues for Snowy 1.0 and Snowy 2.0 cases. The colours show the comparison to the Base Scenario.[17]

[17] The colours show the comparison to the Base Scenario:

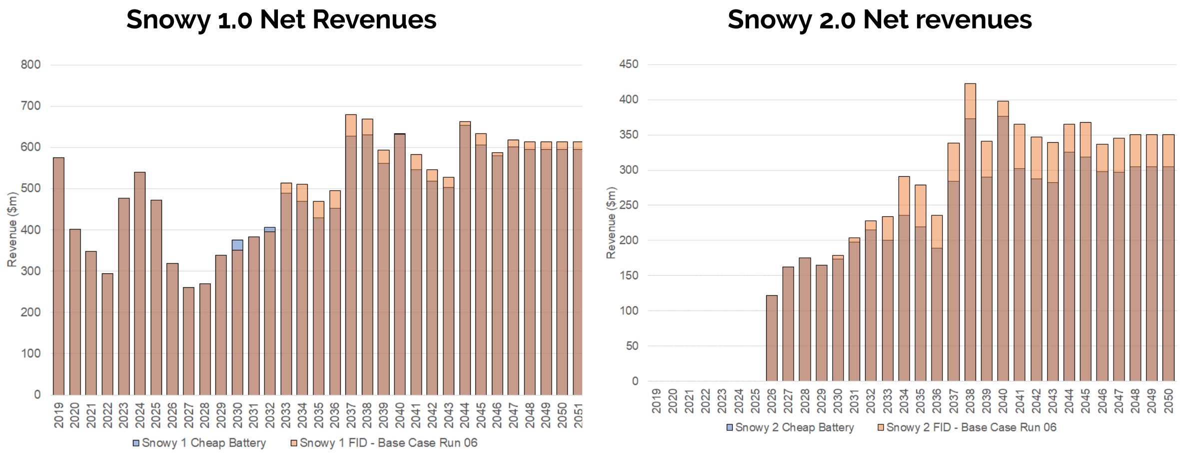


Figure 27: High Battery Scenario – Snowy 1.0 and Snowy 2.0 Net Spot Market Revenues [Source: MJA]

Table 16 below presents the NPV profitability (revenues minus operating costs) for the without Snowy 2.0 and with Snowy 2.0 cases. The net revenues to Snowy Hydro are lower.

Case	Assets	Period		
		2019-2047	2048-2075	Total
No Snowy 2.0				
	Snowy 1.0	8,671	2,320	10,991
With Snowy 2.0				
	Snowy 1.0	7,958	2,654	10,612
	Snowy 2.0	2,336	1,441	3,776
	Total	10,294	4,095	14,389
Change due to Snowy 2.0		1,623	1,775	3,398

Table 16: High battery Scenario – NPV Spot Market Net Revenues 2019 to 2075 [Source: MJA]

4.12 Carbon emissions impact

4.12.1 Overview

This section presents the impact of Snowy 2.0 on total NEM carbon emissions.

4.12.2 Basis of emissions reduction due to Snowy 2.0

The methodology to determine the change in carbon emissions due to Snowy 2.0 was developed to recognise the value in emissions reduction due to the storage provided by Snowy 2.0. By definition, this should include the emissions reduction

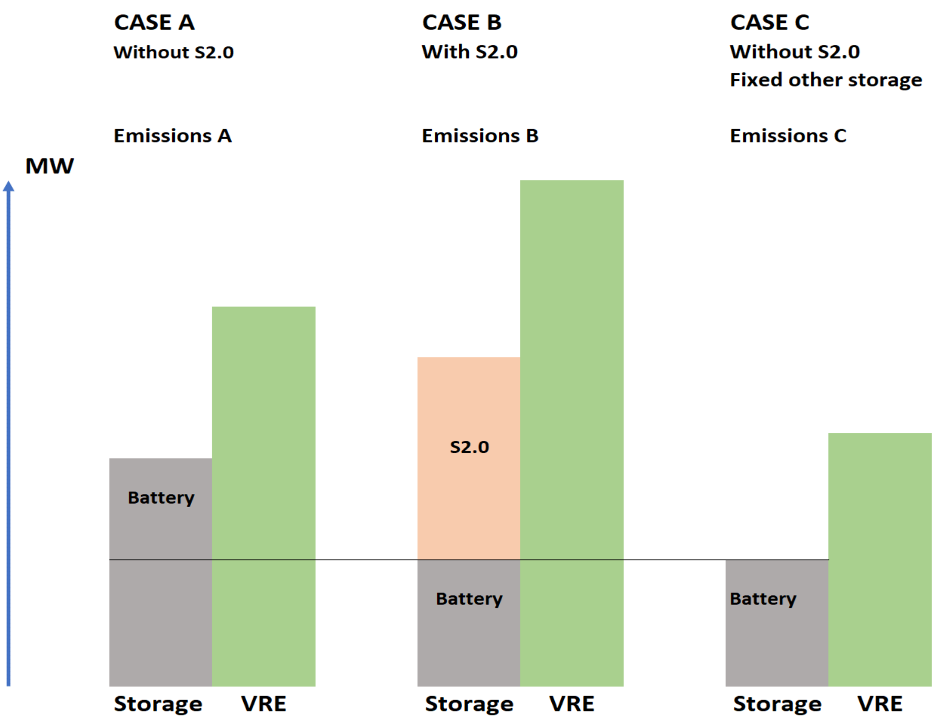
1. The light brown is the Base Scenario;
2. The blue is the case being plotted (ie Low Emissions scenario here); and
3. The dark brown is the overlap of the two cases.

that alternative storage (that would be developed if Snowy 2.0 were not developed) would provide.

This methodology had three NEM development cases identified:

1. Case A: NEM development without Snowy 2.0. This case has:
    a. A level of carbon emissions (Emissions A);
    b. A level of VRE; and
    c. A level storage developed as part of the development of VRE.
2. Case B: NEM development with Snowy 2.0. This case has:
    a. A lower level of carbon emissions than in the 'without Snowy 2.0' case (Emissions B);
    b. A lower level of storage developed due to the storage supplied by Snowy 2.0; and
    c. A higher level of VRE development due the size and nature of the storage provided by Snowy 2.0.
3. Case C: NEM development without Snowy 2.0 but with storage (excluding Snowy 2.0) maintained at that in the with Snowy 2.0 case. This case has:
    a. A higher level of carbon emissions than in Case A (Emissions C);
    b. A lower level of storage developed than in Case A; and
    c. A lower level of VRE development than in Case A.

These three cases are illustrated in Figure 28.



Emissions Reduction due to Snowy 2.0 = Case C – Case B = (Case C – Case A) + (Case A – Case B)

Figure 28: Illustration of Modelling Cases (Not to scale) [Source: MJA]

The level of carbon emission reduction due to Snowy 2.0 is calculated as the change in emissions between Case C and Case B. This can be thought of as the sum of two emission reduction components:

1. The reduction in emissions between the with and without Snowy 2.0 cases when the 'without Snowy 2.0' case includes storage that is not developed in the 'with Snowy 2.0' case (ie Case C - Case B); and
2. The reduction in emissions associated with those batteries that would not be installed if Snowy 2.0 were developed (ie Case A - Case B).

4.12.3 Modelling and results

The assumptions used in the modelling of carbon abatement due to Snowy 2.0 were based on assumptions that formed the basis of the AEMO ISP modelling. With these assumptions the cases modelled were as follows:

1. Emission Modelling with Snowy - 2.0 NEM develops with Snowy 2.0; and
2. Emission Modelling Comparison - NEM develops without Snowy 2.0 and batteries are capped at that with Snowy 2.0

The carbon emissions for the two cases modelled to 2047 and the carbon emissions reduction resulting from the difference between the with and without Snowy 2.0 are presented in Figure 29 below.

This shows carbon emissions decreasing without Snowy 2.0 due to the closure of coal power station and increasing renewable generation. Snowy 2.0 results in a further decrease in emissions due to the additional amount of renewable generation that is economic in the market.

The carbon emissions reduction resulting from the difference between the with and without Snowy 2.0 cases shows a linear ramp down of emissions reduction from that modelled in 2047 to zero by 2070 as shown in Figure 29 below. The total emissions reduction over the period 2026 to 2075 (financial year ending) is 87.83 Mt CO_2e.

Carbon emissions in the cases modelled Mt CO2e **Carbon reduction due to Snowy 2.0 Mt CO2e**

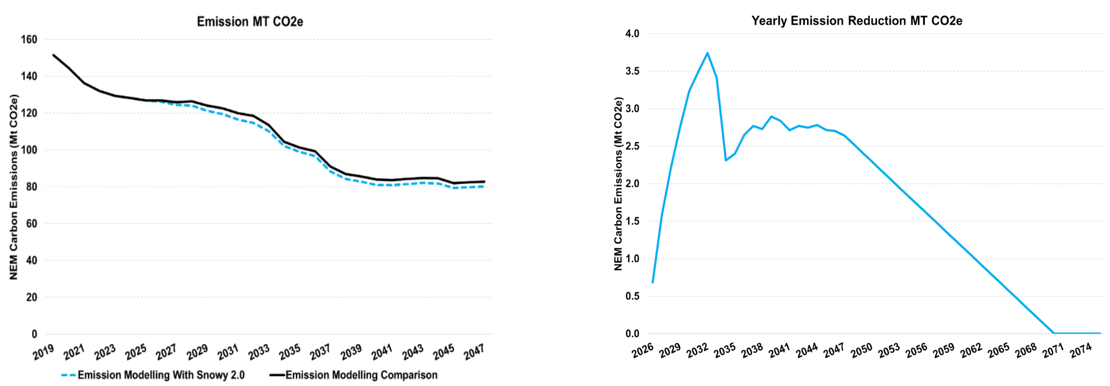


Figure 29: Carbon Emissions and Reduction due to Snowy 2.0 [Source: MJA]

5 Modelling: 'Snowy Hydro Corporate' Scenarios

5.1 Overview

This section provides detailed analysis of the modelling methodology applied for each of the base case and scenarios that are reported within this paper.

The Snowy Hydro Corporate Model scenarios for modelling are presented in Table 17.

Scenario Name	Change from	Description
Base Case		Defensible and commercially robust base case for the Consolidated Snowy Hydro business, including the funding of Snowy 2.0. The cash flows and valuation ascribed to Snowy 2.0 were defined as the difference between: 1. The value of Snowy Hydro with Snowy 2.0, and 2. The value of Snowy Hydro without Snowy 2.0.
NEM downside	Base Case	1. Implied value of Capacity in the NEM is 10% lower than the base case; and, 2. The spread between peak and off-peak Energy value compresses 25% for the duration of the modelled period.
Hydrology Dry	Base Case	1. Immediate and long-lasting effects of less water inflows to the Snowy Scheme; and, 2. Material reductions in the Company's access to fuel
Severe downside capex	Base Case	1. Total outturn capital expenditure exceeds base case by $1.0 billion or 17%.
Consolidated downside	Base Case	Coincident downside factors, the below parameters were aggregated into one case: 1. NEM downside case in which the value of capacity premia revenue drops 5% indefinitely; 2. NEM downside case in which the spread value between peak and off-peak compresses 12.5% indefinitely; 3. A Hydrology Dry case was not included in the consolidated case, primarily because Hydrology conditions revert to the mean over the longer term; 4. Total outturn capital expenditure exceeds base case by $0.5 billion or 8%; and 5. Added 50 basis points on all funding sources indefinitely.

Table 17: Snowy Hydro Corporate Model Scenarios

5.2 All cases - Modelling Results

Scenario Name	Description	Economic outcomes (Project NPV)
Base Case	1. Current policy (LRET, VRET, QRET) 2. Proposed NEG (26% emissions reduction by 2030) 3. Announced generation closures and entry 4. Most likely coal closure program (Eraring, Yallourn, Vales Pt) 5. Most likely new PHES development 6. No emissions reduction target post 2030 7. Rational economics (entry and exit based on economics)	$2.8 billion
Low Emissions	1. Policy for emissions – 45% by 2030, 80% reduction by 2050 2. High rooftop PV (with base assumption on batteries) 3. Hydro Tasmania pumped-hydro storage project developed	$3.4 billion
Coal Early Closure	1. All coal plant closed at the operational age of 50 years	$2.2 billion
High Demand	1. Apply the AEMO high demand case from the 2018 ESOO	$1.9 billion
Hydrology Wet	1. Wet climatic conditions increase inflows for all east coast hydro 2. SHL modelling (pre '25): CP19 Wet sequence 3. MJA modelling (post '25): + 10% inflows p.a.	$2.5 billion
Hydrology Dry	1. Drought reduces inflows to all east coast hydro facilities 2. SHL modelling (pre '25): CP19 Dry sequence 3. MJA modelling (post '25): - 10% inflows p.a.	$2.8 billion
High EV Penetration	1. 50% by 2030; 80% by 2040 (% is cars on the road)	$2.5 billion
Cheap Battery	1. Double battery cost curve depreciation rate	$1.9 billion

Table 18: All cases - modelling results

5.3 Base case

5.3.1 Description

The key objective of this case is to model a defensible and commercially robust base case for the Consolidated Snowy Hydro business, particularly the funding requirements of Snowy 2.0.

5.3.2 Methodology

The focus of the base case is to distil the core principles of the business case for Snowy Hydro, with and without the Snowy 2.0 project, and to report the outcomes in terms of financing capability of the consolidated business and enterprise valuation.

Market modelling methodology

The modelling divided the study period into three development periods:

1. **2018/19 to 2024/25** - This is the period prior to the commencement of Snowy 2.0 and is a period that has a substantial increase in renewable generation;
2. **2025/26 to 2046/47** - This period starts with the commencement of Snowy 2.0 and has the NEM develop from all current coal generators operating except Liddell to when all coal power stations have closed in NSW and only a few remain (in VIC and QLD); and
3. **2047/48 to 2074/75** - This has the NEM basically all renewables supported by firming services provided by storage and gas generation.

The period **2018/19 to 2024/25** was modelled using the internal Snowy Hydro Corporate Model which underpins the board approved 2019 Corporate plan. The long run, 10-year forward curve was provided by MJA as of June 2018 with the short run (first 2 years) having Sydney Futures Exchange (***SFE***) market price superimposed.

The period **2025/26 to 2046/47** was modelled using MJA's PROPHET market simulation model.[18] Using PROPHET, the NEM is modelled on a half hourly basis accounting for the following:

1. Demand variability, generation and transmission operating limits, short-run operating costs, renewable generation variability and correlation to demand and other renewable generators, random outages, and the bidding behaviour of generators accounting for portfolio structure; and
2. In the longer term, the economics of new generation (renewable and non-renewable generators) and retirements as new entry costs change, demand growth, changing transmission etc.

This model produces spot prices, individual generator production and pumping, interconnector flows etc on a half-hourly basis. These outcomes are aggregated to produce quarterly and annual numbers.

The period **2047/48 to 2074/75** was modelled on a less detailed half-hourly basis through a quantitative tool that identifies the requirements for firming services as the proportion of renewable generation increases in the NEM - this model is referred to as the Firming Analysis Model (***FAM***). These requirements included:

1. The level of storage needed in terms of capacity (MW) and GWh of storage to manage the variability of energy production from renewable generators compared to demand;
2. The economic trade-off of storage versus thermal generation (gas) versus additional renewable generation to provide a secure power system; and
3. The percentage of time the market clears on renewable generation, generation from storage and generation from thermal plant.

This model provided for storage needs and the value of storage to be identified, and the associated operation of storage.

[18] The PROPHET model is a highly sophisticated commercial model that has been designed to model energy only markets such as the NEM. It has been used by many NEM participants and has been tested in many complex modelling applications since it first release in 1997. Since 1997 the model has been continually developed.

MJA Market modelling assumptions - development and reasoning

The modelling of the MJA Base Case Snowy 2.0 value was provided by modelling the NEM with and without Snowy 2.0. That is, the environments with and without Snowy 2.0 were assumed to be the same. This is a key assumption that is discussed further below.

The cash flows and valuation ascribed to Snowy 2.0 were defined as the difference between:

1. The value of Snowy Hydro with Snowy 2.0; and
2. The value of Snowy Hydro without Snowy 2.0.

This treatment ensured that Snowy 2.0 was valued only for its true incremental impact on the value of the consolidated business; ie there was no transfer of value from the valuation of the existing Snowy Hydro business to the valuation of Snowy 2.0.

This modelling construct did not evaluate the case in which Snowy 2.0 is not built and the NEM environment faced by Snowy Hydro deteriorates due to the actions of the other NEM players who, in this case, find themselves free to build the required functionality and thereby capture value that would have accrued to Snowy Hydro if Snowy 2.0 was built.

5.4 NEM downside case

5.4.1 Description

The key objective of this case is to model a scenario that recognises over the full term of the Project, including the period between Final Investment Decision (***FID***) and commissioning, a set of assumptions that result in the following:

1. Implied value of Capacity in the NEM is 15% lower than the base case; and
2. The Energy spread between peak and off-peak value compresses 25% for the duration of the modelled period.

5.4.2 Methodology

Pre-commissioning of Snowy 2.0, the Snowy Hydro Consolidated Corporate Model was used to run these sensitivities by making the following adjustments:

1. Capacity:
    a. Cap contracts - capacity revenue was reduced by a discount of 15% on Snowy Hydro's standard, Board agreed New Entrant Price (***NEP***) curve over time. These reductions were made on a consistent basis whether pre- or post-commissioning. In addition, these reduced premia apply only to renewed cap contracts; not to currently written contracts where pricing is contractually locked in; and
    b. Swap load following contracts - Snowy Hydro sells swap load following contracts to both Commercial and Industrial (***C&I***) and Mums and Dads (***M&D***) retail customers. The load shape is bespoke

across a day and thus combines capacity with a standard vanilla swap's energy value.

2. Energy:
    a. Spot revenue - Pre-commissioning modelling of energy value conservatively reduced the peak price by 25%. In other words, the total amount of the spread compression was applied to the value-add upper bound of the price range. This directly reduced discretionary, ie non-contracted, spot prices and thus the spot revenue obtained; and
    b. Contract revenue - Snowy Hydro sells swap load following contracts to both C&I and M&D retail customers. While M&D swap load following energy is sourced internally from scheme inflows, C&I energy is a contracted buyback and is thus a pass-through cost. Thus, when the forward curve peak price is reduced by 25%, the resultant decrease in energy value is only applied to M&D swap load following contracts. Moreover, as 20% of the total value is capacity value, the energy value reduction affects only 80% of the total swap load following value.

Post-commissioning of Snowy 2.0, the MJA modelling was used to run these sensitivities, the output of which was then loaded into the Snowy Hydro Consolidated Corporate Model. Given this exercise is contemporaneous to the pre-commissioning modelling, checks were made on the key metrics in the transition from pre- to post-commissioning phases.

The fundamentals that could potentially lead to this downside scenario were assumed to be:

1. Existing coal plant is maintained in service longer, resulting in additional coal generation in service from 2025 to post 2050 and higher coal prices; and
2. Thus, the existing coal plant results in a lower amount of renewable generation being developed than would have been the case.

The steps that MJA team undertook in producing the output compared to the base case:

1. While Snowy 1.0 energy value is primarily concerned with uncertainty around the sell price of spot revenue, the sensitivity to value for Snowy 2.0 is the peak-to-offpeak spread. This means the risk to Snowy 2.0 value is not only a reduction in spot sales revenue (generation) but also an increase in spot buy cost (pumping). MJA, therefore, stressed these risk factors by a reduction in 25% of net revenue.

The result for pumped hydro operation in the spot market is:

1. Higher pumping prices due to higher coal generation prices and a reduced amount of time Snowy 2.0 is using zero cost renewable generation;
2. Lower prices for generation sales in the spot market due to an increase in the amount of dispatchable generation and lower price volatility; and

3. An average decrease of 25% of the buy/sell net revenue over the period 2025 to post-2050:
   a. **Capacity:**
      i. Analogous to pre-commissioning modelling, capacity revenue was reduced by a discount of 10% on Snowy Hydro's standard, Board agreed NEP curve over time; and
      ii. NB MJA fundamental economic modelling makes no assumption about the existence of exotic contract types, such as swap load following contract. MJA calculates Snowy Hydro value in terms of spot and cap contract outcomes only.
   b. **Energy:**
      i. The MJA result for Snowy 1.0 operation in the spot market is a reduction in the average price of generation sales of about $10/MWh.

5.5 Hydrology Dry

5.5.1 Description

The key objective of this case is to model a scenario that contemplates immediate and long-lasting effects of lower water inflows to the Snowy Scheme, resulting in quite material reductions in the Company's access to fuel.

5.5.2 Methodology

The approach to this scenario in the pre-commissioning phase simply leverages the work that is conducted within the annual Corporate Plan modelling process. Each year the Company spends considerable effort modelling a Dry case, and below are the latest assumptions and structure utilised in the most recent Corporate Plan:

1. The Hydrology Dry scenario utilises a series of inflows that represent two consecutive cumulative five year inflow periods that represent a 90% probability of exceedance (ie a less than 10% probability of occurring over any five year period). The inflow series for this scenario was selected from a subset of historical inflow data that is representative of recent climatic indicators that are applicable over the Corporate Plan Period. Under this scenario there is no impact to the financial outcomes for the Snowy 2.0 development given that it utilises recycled water resource; and
2. The forecast active Scheme storage level at the end of the Plan Period for the Hydrology Dry scenario is 16% (837 Gl), compared to 48% (2,542 Gl) for the Base Case. Notably, the inflow reduction compared to long-term averages for this scenario is less severe than that experienced during the all-time record low Scheme inflow in 2007.

Post-commissioning of Snowy 2.0, the MJA modelling was used to run this sensitivity, the output of which was then loaded into the Snowy Hydro Consolidated Corporate Model. The MJA team were tasked with running the NEM model under severe water availability constraints that effectively reduced annual

Scheme inflows by 10% from 2025 onwards in perpetuity. For this sensitivity, MJA undertook the following steps with associated results:

Snowy 1.0

1. Snowy 1.0 annual generation from water inflows decreases by 10%. However, 1.5% is recovered through additional Tumut 3 pumping but this has an associated cost of the energy of pumping. With the cost of pumping (accounting for pumping losses) about 35% of the sales price, this is equivalent to a decrease in Snowy generation from water inflows of about 9%; and
2. The value of the reduced sales is the price at which Snowy is prepared to sell. In other words, the sales foregone are the lowest priced sales at the margin. With the average price of sales at $90 the lowest priced sales are about $72. This is $18 below the average cost.

Snowy 2.0

1. Snowy 2.0 is not impacted by drought as generation is from pumped water. The drought and reduced generation from Snowy 1.0 slightly increase the selling price of generation, however there is no increase in the buying price for pumping; and
2. The slight increase in selling price provides for Snowy 2.0 an economic increase in the amount of pumping and generation undertaken. This increase has been shown to be over 50% of the lost sales from Snowy 1.0. The value of this is at a higher price than received by Snowy 1.0 due to the lower utilisation of Snowy 2.0 compared to Snowy 1.0.

5.6 Severe downside capex case

5.6.1 Description

The key objective of this case is to model a scenario that contemplates total outturn capital expenditure exceeds base case by $1.0 billion or 17%. There is no elongation in the Project's delivery schedule for this scenario which means the existing operations of Snowy Hydro and Financiers would be required to fund the additional capex, over the same S-curve profile. This scenario implies that there has been $1 billion worth of client-retained risks that have materialised with a severe financial impact, but no net impact on the critical path of the Project.

5.6.2 Methodology

The approach to this scenario is simple in approach and carefully checked back to the best and latest information available to the Project. The base case $5.9 billion capital expenditure is a value that has been arrived at from multiple lines of investigation:

1. Cost estimating, project scheduling and quantitative risk assessment (***QRA***) services provided by Turner and Townsend;
2. Feasibility Study investigations, with additional due diligence and design efforts added since; and; and

3. Indicative pricing that has been garnered through the 18-month early contractor consultation (***ECC***) process.

The approach to sensitising this capex estimate is simple:

1. Upside case is $5.4 billion or $0.5 billion less than base case;
2. Downside case is $6.4 billion or $0.5 billion more than base case; and
3. Severe downside case is $6.9 billion or $1.0 billion more than base case.

In determining the strength of these $0.5 billion increments, many other factors (not discussed here) must be considered, including the Engineer-Procure-Construct (***EPC***) contract structure risk sharing mechanisms and project flexibility to respond to various events in a commercially acceptable manner.

5.7 Consolidated downside case

5.7.1 Description

The key objective is to arrive at a consolidated business case that contemplates the factors that could occur in parallel such that the financing of Snowy 2.0 and existing business operations becomes materially affected on the downside, and test the resilience of cash flows and financing structure under that scenario. This case also contemplates what would or could happen to borrowing costs, as well as the requirement for a significant piece of subordinated financing and the cost thereof.

5.7.2 Methodology

In order to arrive at a consolidated downside case that combines a number of coincident downside factors, the below parameters were aggregated into one case:

1. NEM downside case in which the value of capacity premia revenue drops 7.5% indefinitely;
2. NEM downside case in which the spread value between peak and off-peak compresses 12.5% indefinitely;
3. The Hydrology Dry case modelled in the 2019-2028 Corporate Plan was not included in the consolidated case because climatic conditions revert to the mean over the longer term, and while it is useful as an independent scenario, in aggregate with other downside scenarios it is not normally included. The logic for not including it in the consolidated downside case is primarily because it is not as transparent as to the impact on the Company's financial position because in reality, many strategic responses would be employed, such that the effect would be softened;
4. The Retail downside case that was modelled in the 2019-2028 Corporate Plan was included in the consolidated case. This case models an unfavourable regulatory impact to Retail margins which could be imposed via a number of different channels - AEMO, Thwaites Review,[19] AER and

[19] (Thwaites et al. 2017).

ACCC/Federal Government proposal for default pricing option,[20] for example. During the peak financing years of 2020-2025, this case reduces the Retail EBITDA margin by 14%, and over the longer 10 year horizon, it reduces the margin by 9%. This profile is viewed as negatively impacting the peak financing periods most materially and therefore tests the resilience of the financing the best;
5. Capex downside case of $6.4 billion in total outturn dollars; and
6. Added 50 bps on all funding sources indefinitely.

The consolidated downside case was then reported under two funding structures

1. Equity + Internal Cash Flow Generation + Senior Debt; and
2. Equity + Internal Cash Flows Generation + Subordinated funding of $1 billion + Senior Debt.

5.8 The 'Black Swan' downside case

5.8.1 Methodology

The 'Black Swan' case takes the Consolidated downside case and adds the Hydrology Dry case.

1. The Hydrology Dry case modelled in the 2019-2028 Corporate Plan was included in the 'Black Swan' case, primarily to test the resilience of cash flows in the peak financing years for the Project. This case ignores the many strategic responses that would be employed in order to soften any impact on cash flows and business resilience including financeability.

The 'Black Swan' downside case was then reported under two funding structures:

1. Equity + Internal Cash Flow Generation + Senior Debt; and
2. Equity + Internal Cash Flows Generation + Subordinated funding of $1 billion + Senior Debt.

6 Definitions and abbreviations

AEMO	Australian Energy Market Operator
C&I	Commercial and Industrial
CCGT	Combined Cycle Gas Turbine
CSG	Coal Seam Gas
ECC	Early contractor consultation
EPC	Engineer-Procure-Construct
ESOO	Electricity Statement of Opportunities
EV	Electric Vehicle
FAM	Firming Analysis Model
FID	Final Investment Decision
GPG	Gas Power Generation
ISP	Integrated System Plan

[20] (AER 9 nov, 2018).

LNG	Liquefied Natural Gas
LRET	Large-scale Renewable Energy Target
M&D	Mums and Dads
MJA	Marsden Jacob Associates
NEG	National Energy Guarantee
NEM	National Electricity Market
NEP	New Entrant Price
NPV	Net Present Value
OCGT	Open Cycle Gas Turbine
QRA	Quantitative risk assessment
QRET	QLD Renewable Energy Target
RES	Rating Evaluation Service
RET	Renewable Energy Target
REZ	Renewable Energy Zones
RTE	Round Trip Efficiency
S&P	Standard & Poor's
SFE	Sydney Futures Exchange
SRMC	Short Run Marginal Costs
VRE	Variable Renewable Energy
VRET	Victorian Renewable Energy Target

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