Cost, Reliability, and Emissions.

Nuclear power solves the Australian electricity supply trilemma.

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Summary

A new electricity generating mix model finally allows the evaluation of all feasible options for the replacement of Australia's ageing base load generation assets. Over the period 2022 to 2050 approximately 20,000 MWe of base-load generating plant will need replacement. There is no national plan for this critical issue and ongoing debate has been hampered by ideology on all sides of the political divide.

A range of possible options have been widely promoted across the Australian community and media. Very little understanding has been shown for whole of system design requirements, cost, reliability, and emission outcomes for these options. Many are not actually feasible and this leads to wide spread misinformation. Important factors for each option system have also not been ready available for decision makers. This paper documents the relative costs, benefits, and overseas experience for coal, gas, nuclear , and renewable generation options for progressive replacement of Australia's electricity generation fleet.

The recommended outcome is for the introduction of nuclear power in public ownership based on reliability and emission criteria at a cost only marginally above that of coal or gas. While a well engineered renewable generation option offers acceptable low emissions the total cost to achieve a reliable outcome at double that of the nuclear power option is unacceptable.

An additional paper covers all aspects of a recommended nuclear power implementation program for Australia.

INTRODUCTION

Over the past two decades the utility of the Australian electricity sector has deteriorated markedly. A combination of privatisation of public assets, renewable subsidies, and poorly designed liberalised markets has led to the current situation. In addition the reliability of the electricity generation fleet is deteriorating because owners are cutting back on maintenance to enhance profits. The collective end result is that costs to residential and industrial consumers have risen from world's lowest to close to world's highest with predictable impacts on all consumers but of deeper concern for Australia's industrial base.

The reasons for this include failure of the market as currently designed to include payments for capacity, the negative impact of renewable subsidies on base-load utilisation, gaming, and generator/retailer market power. Most inquiries show little or no understanding of the complexities of power system engineering, despite much repeated claims that such reviews are technology neutral or technology agnostic. Appropriate technology and excellent engineering is crucially important to ensure lowest overall cost, technical standards, and reliable operation every second. Poor choices promoted for the existing and future electricity sector have already led to expensive mistakes that will bedevil many households and Australian prosperity as a nation for years to come.

This paper provides a strategy to address the failure of any long term planning or provision by the private sector for future base load generation investment.

THE ELECTRICITY SECTOR INVESTMENT DILEMMA

Electricity sector generation asset replacement for Australia is a policy and planning issue currently left to the market. Markets by their competitive nature are unable or prefer not to collectively respond in any way that addresses the national interest. A classic 'Tragedy of the Commons' issue. The investment problem is driven by the fact that the current liberalised market provides no reliable long-term guarantee for return on capital investment for new base load generation. An energy only market where the only chance for plant utilisation and financial return is settled every half hour gives no security or incentive to investors who may wish to provide capital for new base load facilities. No bank, local or international will provide debt funding to support equity investment under these circumstances.

At the highest level this situation is totally at odds with all acceptable organisation governance principles for both the public and private sector and if allowed to continue will lead to a worsening situation for all aspects of the electricity sector and consumers. Interesting to note recently that engineers predicted the collapse of the Genoa road bridge ten years ago but widespread procrastination by opportunistic politicians prevented implementation of an appropriate solution.

Some commentators and renewable sector lobbyists have promoted the concept that base-load generation will no longer be required and is an impediment to the more widespread deployment of renewable energy. This concept may be true if costs to electricity consumers are of no concern and reliability is of minor importance. Detailed engineering system analysis shows that coal, nuclear or gas base load power will continue to be required for the foreseeable future to underpin the reliable provision of electricity to current technical standards at acceptable cost.

Unpredictable levels of solar and wind power operation will always require quick start backup response, transmission augmentation, and system quality management. This results in higher costs than base load power generation of any type.

ANALYSING THE INVESTMENT OPTIONS

This paper takes information from a preliminary investment proposal document that provides the basis for future electricity generation investment in Australia and New South Wales. That study is based on detailed engineering system design with supporting economic analysis to achieve lowest cost and lowest emission outcomes for a fully reliable system that could support the National Energy Guarantee concept. The proposal does not promote large scale demand management as this is an inappropriate high risk response to inherent system failure particularly for industrial consumers in a modern society.

A range of energy generating mixes that have been promoted by institutions and individuals have been analysed using load and generation data provided by the Australian Energy Market Operator for each period of 30 minutes over the year 2017. This represents 17,520 data sets analysed for the current and typical future system, winter/summer, day/night electricity load demand pattern utilising all feasible generation combinations available for the Australian electricity sector. Only this level of analysis picks up the real impact of intermittency of solar and wind generation and what is required to fix this problem.

The system engineering model first matches the actual load demand at each data point with a feasible generation combination to ensure all demand is met at all times. Some proposals are shown to be not operationally feasible. When balance is achieved the final generation mix is costed, transmission, distribution and retail costs are added and a cost to the consumer is calculated. A minimum cost can be quickly achieved by optimising the generation mix. The model mirrors the actual working of the Australian grid and current National Electricity Market to provide all relevant output values for decision makers. The model allows analysis of future options in a depth not seen in any other form of publicly available analysis to date. The majority of previous modelling efforts fail to reflect system engineering reality by using averaging concepts for individual generation options. These assumptions smooth over intermittency and asset underutilisation cost issues. Simplistic economic concepts are unacceptable in real engineering analysis which must account for and manage all extremes. Details of the model used to provide option studies for this paper are available at https://epc.com.au/

All costing data has been taken from actual capital and operating values outlined in the AEMO Integrated System Plan 2018. Information for the nuclear power option was provided by South Korean government agencies during an intensive study tour of that country believed to be the most efficient electricity provider in the world. The Korean costing information was revised by Australian consultants and contractors to ensure compatibility with labour rates and general civil engineering costs currently seen on local major projects.

The model allows financial analysis over a range of discount rates to give an assessment of options for public and private funding. These two financing options have markedly different outcomes for the same asset investment. Private sector organisations require a cost of capital return of up to 12% (typically 20% equity 80% debt) whereas public investment can be managed for 3% interest rates or less.

ANALYSIS OUTCOMES

Outcomes from a selection of possible generation options are shown in Figure 1.

Full supporting details are provided in Appendices 1 and 2. These cover the National Electricity Market as it currently operates together with a range of low emissions technologies using gas, renewable solar and wind and nuclear power. The cost of carbon dioxide emission abatement is also calculated.

While all load is met for each case to ensure comparable reliability, further analysis is required to ensure grid system quality standards and stability is maintained for the higher level non synchronous renewable options.

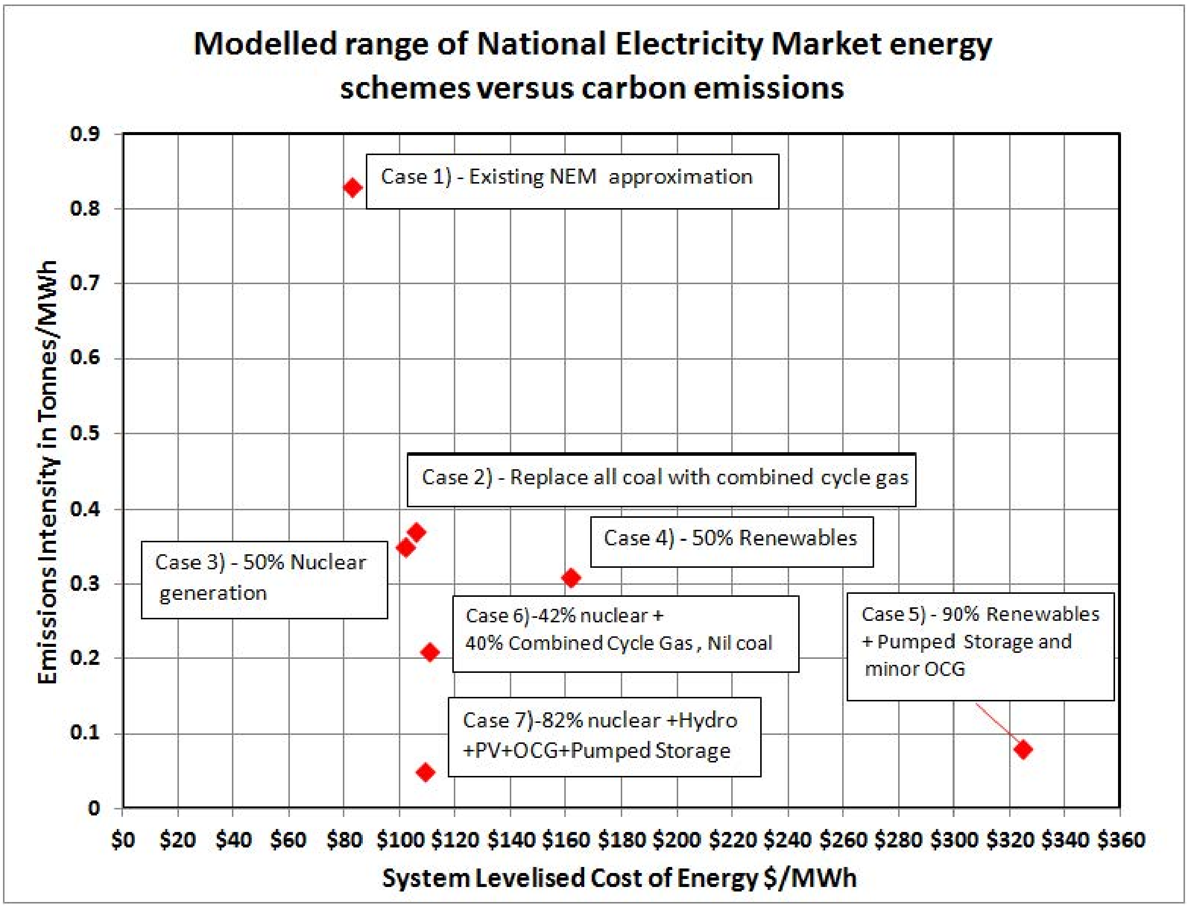


Figure 1 - Cost and Emission outcomes

The illustrations of load and supply in Appendix 1 show the significant impact of behind the meter solar installations which may benefit cost reduction and emissions output during the daily peak demand.

Figure 2 illustrates the system retail cost impact of increasing percentages of renewable and nuclear electricity sources in the NEM grid. Two key factors combine to progressively drive up the cost of solar and wind renewable generation options.

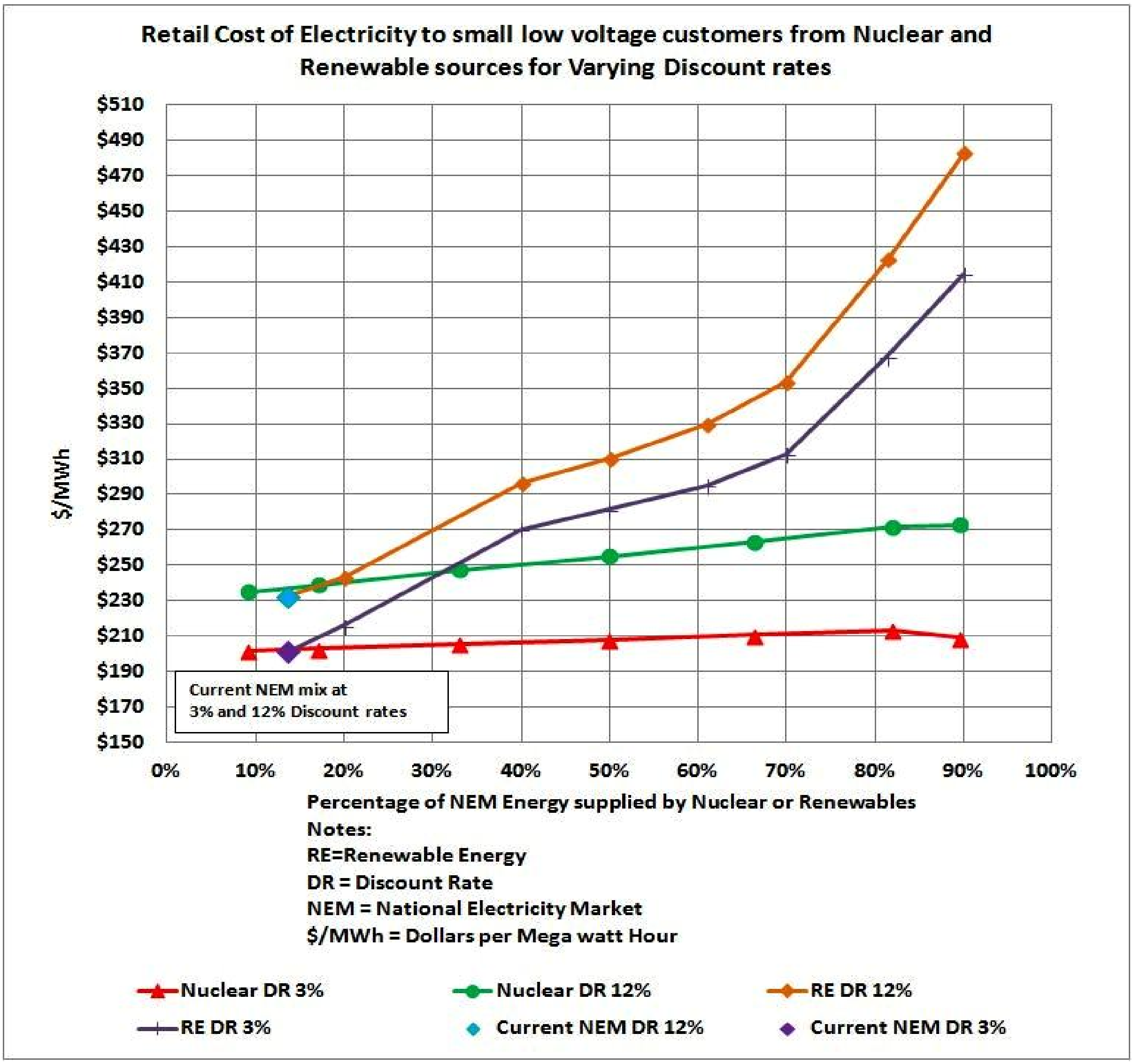


Figure 2 - Nuclear Energy Cost Competitiveness

The random capacity and intermittent output requires the provision of quick-start open cycle gas turbine capacity to augment existing hydroelectric capacity and new pump storage capacity. The use of grid level electrical storage batteries is not a viable economic option. As renewable generation increases transmission costs also markedly increase. Lower capacity factors of renewable energy cause lower utilisation of the transmission network and therefore higher transmission costs. Analysis shows that benefits from wind and solar PV diversity across the NEM are quite marginal and come nowhere near providing a base load capability.

The analysis reflects the actual intermittency across all Australian wind farm installations. Studies from across Europe confirm similar very minor intermittency reduction for multiple wind farm installations.

THE LOWEST COST LOWEST EMISSION OPTION

If emission reduction is accepted as a serious imperative then only nuclear power provides this outcome in a reliable cost-effective manner as this investigation verifies and experience from France, Sweden, Korea and China demonstrates. Figure 3 illustrates the relative cost of carbon dioxide abatement measures for increasing levels of renewable and nuclear power generation in the NEM

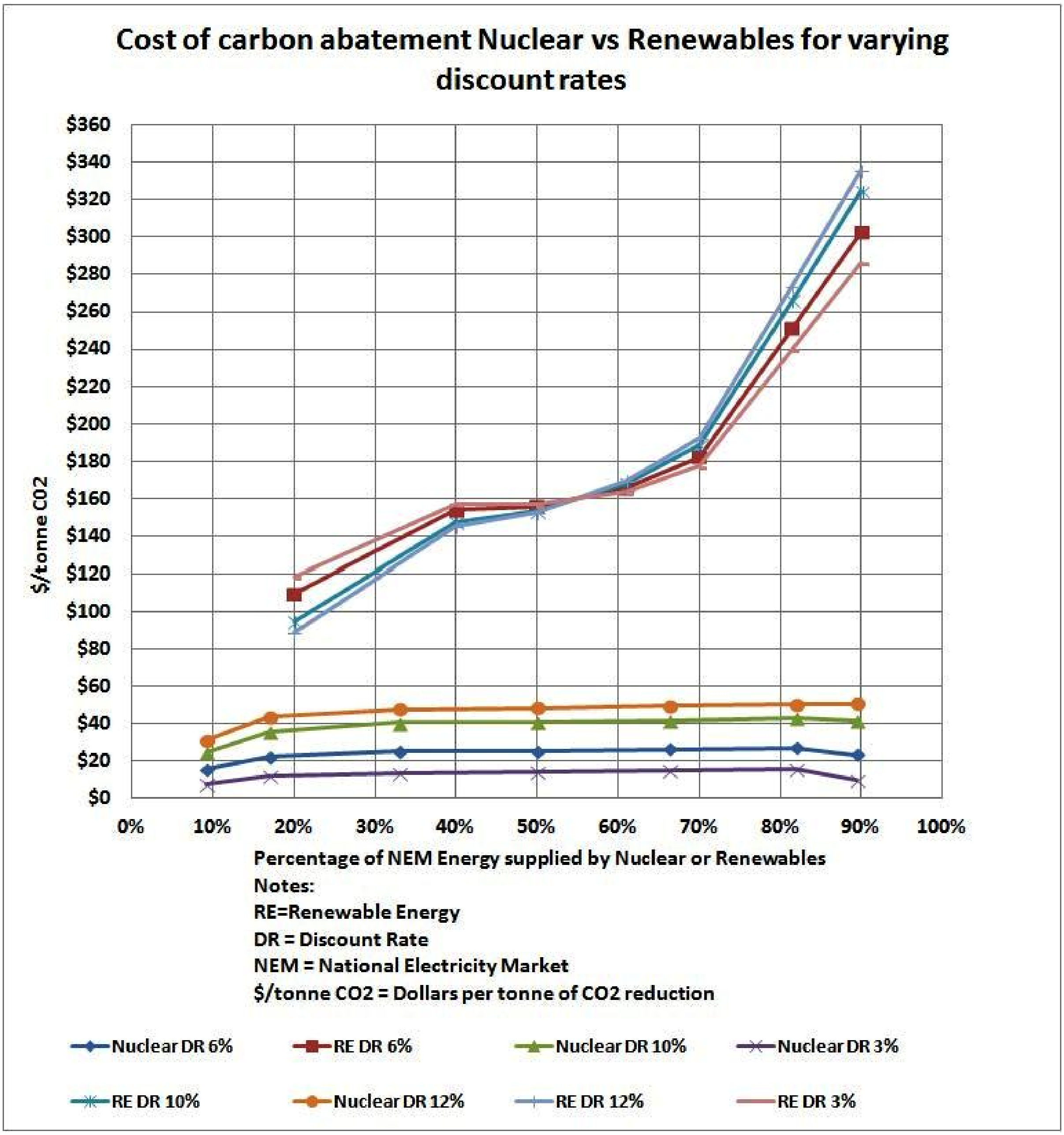


Figure 3 - Carbon Abatement costs comparison, Intermittent Renewables vs Nuclear Energy

THE IMPLEMENTATION PROGRAM

The opportunity for a managed transition of retiring coal fired generation directly to nuclear power generation in the National Electricity Market (NEM) needs prompt attention. At least one new coal or gas fired power station will probably be required to replace Liddell in NSW before the first nuclear power units could be commissioned . There is currently no proposal to replace the Liddell generator with base load capacity illustrating the extent of the investment issue.

The investment failure crisis can only be overcome by the provision of minimum 15 year power purchase agreements provided by government to the private sector or alternately by direct investment in the electricity sector by government. The economic analysis illustrates that these two financing options have markedly different financial outcomes for the same asset investment. This leads to system levelised costs for base load private and public investment as noted in Appendices 1 and 2. Inherent in both these possible investment options is the need for electricity supply from both to operate outside of the existing liberalised market to ensure full plant utilisation and secure investment return. In one sense both options constitute a payment for long term capacity at lower cost than currently seen in the national energy only market.

The analysis leads to the conclusion that if cost of supply is important, new base load investment should be undertaken directly by government in advance as ageing private generation assets are slated to be retired. This option is already being discussed for some generation capacity such as high efficiency coal and large scale pumped storage. The most likely plant retirement program is well understood and is not detailed beyond Figure 4 in this document.

A well defined government investment strategy for nuclear power will likely stabilise the current market so that price increases driven by plant closures as seen in the past will not be repeated. It is accepted that great care must be exercised with such a policy concept to ensure that the current market arrangements including renewable subsidies do not continue to prematurely disadvantage existing base-load generation technically and economically. This disadvantage arises by forcing under-utilisation and premature closure driven by inappropriate financial conditions as was illustrated by the Northern and Hazelwood generation plant closures.

A review of the current base load power station retirement program for the NEM generation assets and information gathered from South Korea indicates the following action proposal. It is recommended that the Federal parliament initiate an investment program to build at least 20 number1000 MWe nuclear power plants to be progressively commissioned over the 20 year period 2030 to 2050. The capital cost will be A$6.2B for each 1000 MWe unit, approximately A$130B in total for a full reactor fleet.. The program will be completely cost neutral for a generation sale price direct to consumers or through the NEM of 8 cents per kilowatt hour while supporting the full intent of the National Energy Guarantee as it now stands.

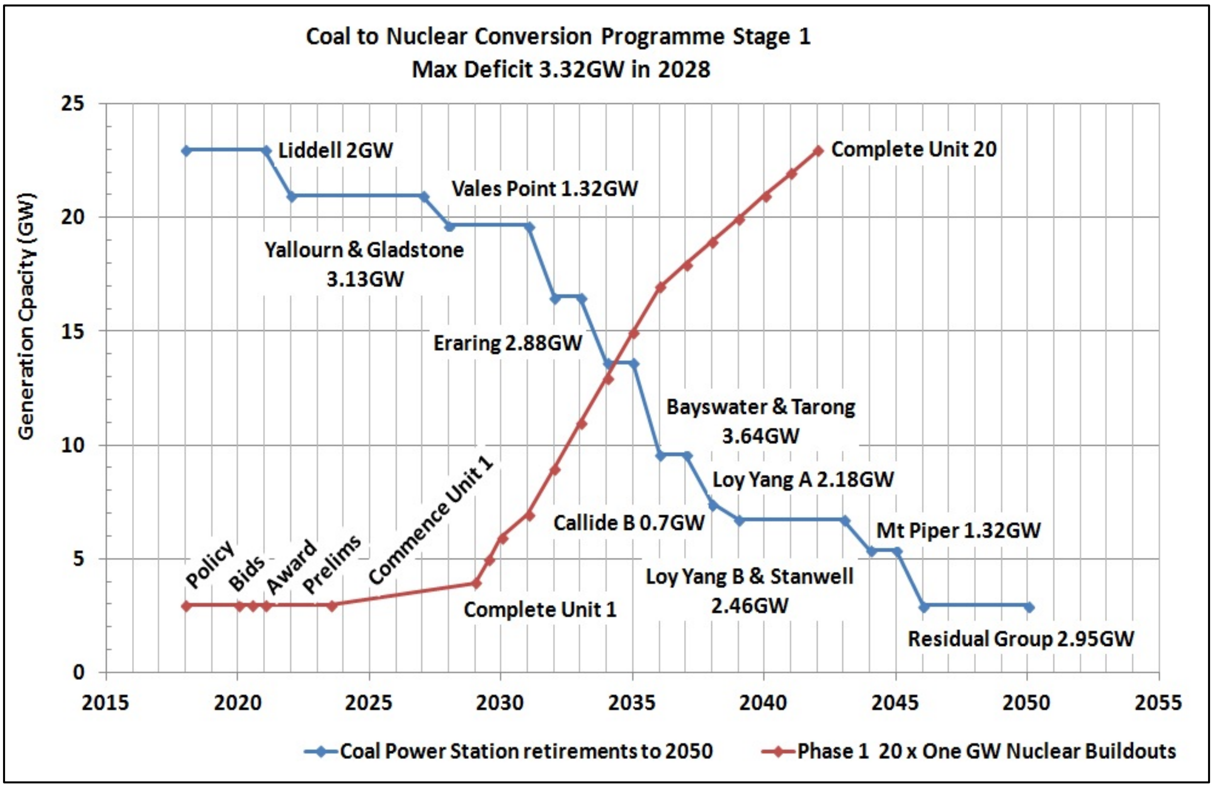


Figure 4 - Coal to Nuclear Transition

THE IMPLEMENTATION ENGINEERING RECOMMENDATION

The generation units recommended for installation are the APR1000+ pressurised water reactors (PWR) designed and manufactured by South Korea. These units are an updated version of the OPR1000 unit which have a long history of development and world class reliable operation with over 10 units now in operation. Excellent local and export performance has seen recent 1400MWe versions of these units constructed on time and on budget; a factor of the utmost importance for investments of this nature. The larger units although more cost efficient are not suited to the current NEM grid but may be in the future. There is no other nuclear plant option currently available that provides the opportunity for early ordering together with the lowest overall risk profile and value for money at this time.

Small modular reactor power plants hold out the promise of significant advantage in terms of siting options and factory based manufacture for the future. These units could not be recommended for installation in Australia until costs are verified and significant operating experience has been gained in countries of origin. This is expected to be achieved within about 10 years

The nuclear industry and electricity supply for South Korea is fully managed by government with minority public shareholding while manufacturing and construction capability is provided by the private sector. Electricity is provided to the nation as a service by the public sector to stimulate wealth creation throughout the entire economy. Unfortunately as electricity pricing in Australia now shows the supply of electricity as a tradable commodity is strangling this nation's wealth creation. In South Korea the average electricity price to all consumers is US8c/ kWh. The 30% nuclear power contribution is provided at around US4c/ kWh. This performance model could easily be utilised throughout Australia with the benefit of sharing all financial aspects of the initial investment in the form of a public / private arrangement.

It is recommended that the first two units for Australia be fully contracted from South Korean suppliers on a turnkey basis. That country is dedicated to supporting progressive local manufacture of future units. Australia already has most of the infrastructure and technical expertise necessary to achieve local construction for later units and the potential for export of manufactured components to other developing countries. The flow on economic benefit over the 20 year implementation period would likely exceed A$200B. The well managed Korean government program has seen industry growth to world class levels and economic benefits well beyond these proportions.

CONCLUSION

Detailed system engineering and economic analysis has shown that the implementation of a nuclear power investment program by government provides the lowest cost, lowest emission outcome for Australia's future electricity sector. Nuclear generation units will have an operational life of at least 60 years providing low cost supply of energy for the foreseeable future. An additional pre-feasibility study outlines all information required for an investment proposal as recommended by Federal Government Guidelines for Major Projects. The proposal covers every aspect from detailed investment justification to project risk management.

Reports from the study of South Korean nuclear installations are available at http://www.nuclearaustralia.org.au/ .

DOCUMENT CONTRIBUTORS

Mr. Barrie Hill was formerly Principal Consultant Mining and Energy for Jacobs Australia, Director of Engineering for the Australian Nuclear Science and Technology Organisation (ANSTO) and General Manager Queensland Magnesia. He was a Founding Director of the Queensland Mining Council and the Hargraves Institute for Innovation. Mr. Hill has an extensive background in major project analysis and implementation, power station engineering including nuclear, and process plant development and operations. He is a Fellow of Engineers Australia and Member of the Institution of Mechanical Engineers.

Dr Robert Barr AM is a consulting engineer, director of his company Electric Power Consulting Pty Ltd. Robert has over 42 years experience in the field of power systems and electricity distribution, is a Fellow of Engineers Australia and a member of Consult Australia. Robert is an Honorary Professorial Fellow at the University of Wollongong and was awarded the title of Australian National Professional Electrical Engineer of the year in 2012. Dr Barr became a Member of the Order of Australia in 2013.

Robert's contribution to this paper relates to the construction and application of the NEM model. Robert maintains a "technology neutral" approach to the development of the NEM of which this paper is an important contribution.

Mr. Robert Parker is a civil engineer with over 35 years of experience in project management and the economic evaluation of projects. He is the former President and current committee member of the Australian Nuclear Association. He holds a Masters in Nuclear Science from the Australian National University. In 2015 Rob attended the International Congress on Advances On Nuclear Power Plants in Nice (ICAPP 2015)where he signed the Nice Declaration along with the national representatives of 38 other nuclear associations. This declaration advocates the use of nuclear energy to address man made climate change by ensuring that 80% of electricity comes from low-carbon sources by 2050.

Appendix 1 - Case Studies of Potential Base Load Generation Replacement Options

Case 1) - The existing national Electricity market of black and brown coal, open and closed cycle gas with limited renewables delivered by hydro, solar and wind.
Case 2) - The replacement of all coal with combined cycle gas for baseload and maintaining the remainder of the NEM energy generation as is.
Case 3) - Use of 50% nuclear energy plus an expanded renewables and pumped storage capacity with substantial backup from fossil fuelled generators operated at lower capacity factors.
Case 4) - Use of renewables consisting of expanded wind and solar plus existing hydro and augmented by pumped storage.
Case 5) - 90% renewables with large scale pumped storage and a small level of open cycle gas generation.
Case 6) - Coal replaced by 42% nuclear energy and 40% combined cycle gas plus pumped storage, hydro, open cycle gas and solar PV.
Case 7) - 82% nuclear generation. Daily peaks are served by pumped storage, solar PV, open cycle gas and hydro.

Notes:

1. The full modelling inputs and results are shown for Case 1 to illustrate electricity transmission costing detail. Other cases use similar input methods and details but not all modelling outputs are provided in this Appendix - they are available if requested.
2. The tables for each case list the costs of generation for all case results, namely:
    a. The System Levelised Cost Of Electricity (SLCOE) which includes the transmission costs specific to that case
    b. The final retail cost to consumers and
    c. The CO_2 abatement cost over and above Case 1 the current NEM average emission level.
3. The hydro generator values have been varied in the cases to ensure the hydro generation output under each case remains at 8% of NEM demand.

4. The illustrations showing generation output for each case have been limited to a 20 day snapshot from the 1st July 2017 to 21st July 2017 - this is for visual clarity. The full year spectrum is available.
5. Pumped storage plays an increasingly import part in both renewable and nuclear cases. The nuclear cases make use of solar PV plus hydro plus pumped storage plus gas to meet the daily peak loads. This can be viewed at finer detail in the following image covering a seven day period.

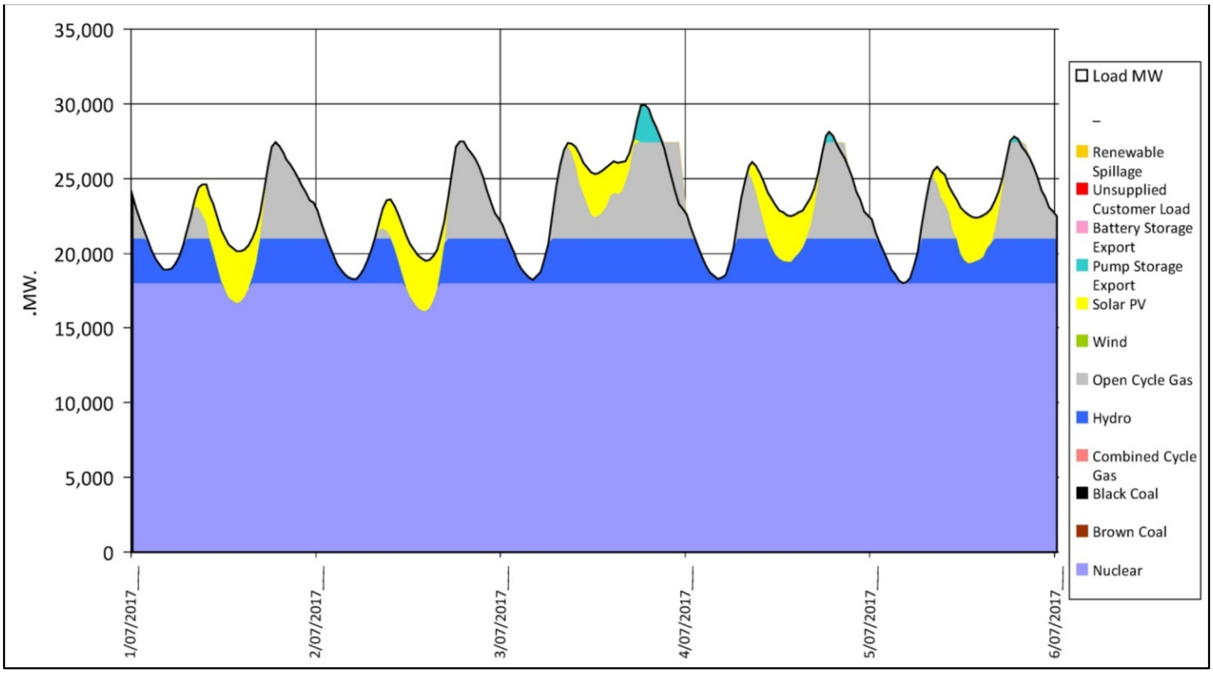


Figure 5 - Seven day snapshot of 82% nuclear power generation case meeting NEM energy

6. The models use generator costs obtained from the AEMO "integrated System Plan" July 2018 and its supporting documents. Costs for existing coal power plants used in the model also use these latest values to replicate the current NEM generating costs.
7. **System Levelised Cost of Electricity** (SLCOE) being the final system cost which incorporates all the types of generation in the mix. The commonly quoted Levelised Cost of Electricity (LCOE) is frequently thought of as being a constant value. It is not. The LCOE varies according to how much time the output of a generator actually contributes to the system and of course, how much of its energy is either curtailed or wasted. The output from the model developed by Dr

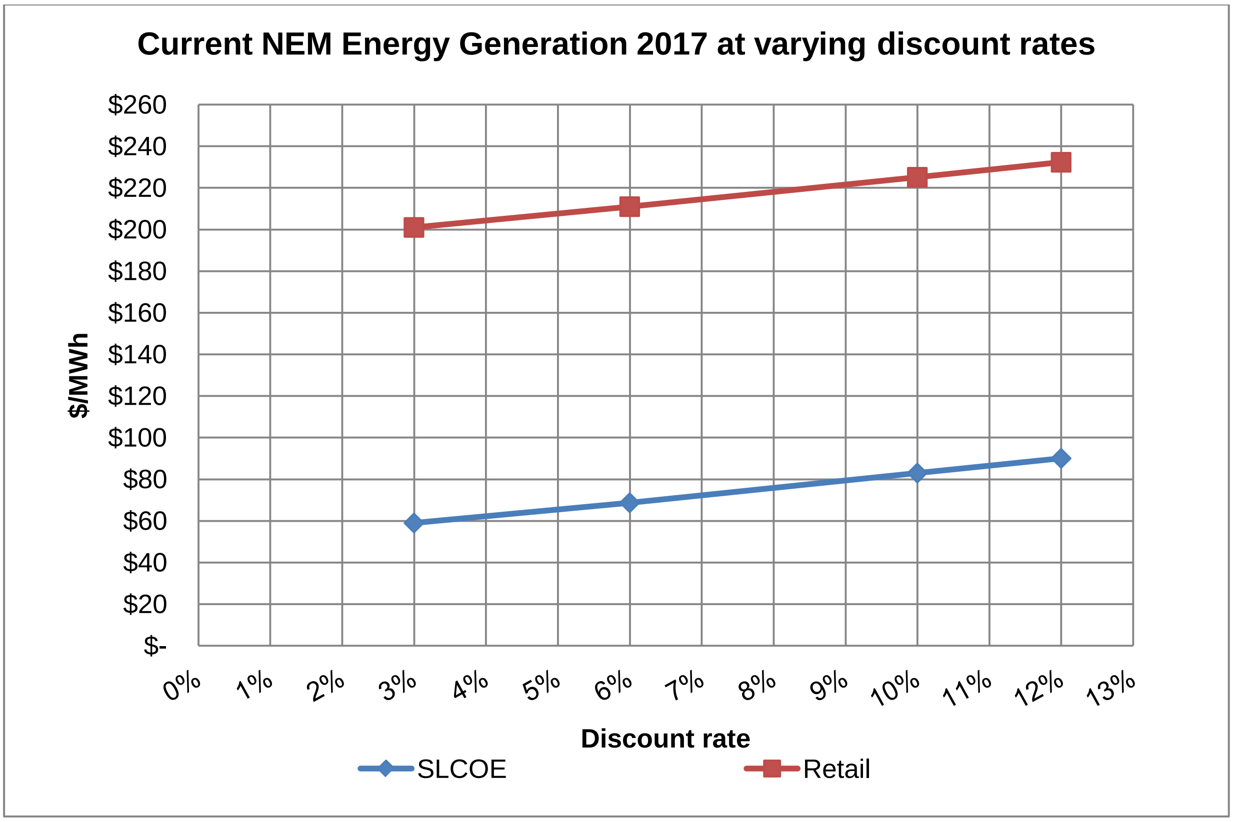
Robert Barr fully accounts for the varying LCOE of each generator and adds an allowance for additional transmission to produce a final system cost or SLCOE

CASE 1 - CURRENT NEM GENERATION MIX DIRECT REPLACEMENT

GenTypeDesc	Installed MW	Storage Days
Nuclear	0	
Brown Coal Supercritical	3,000	
Black Coal Supercritical	14,000	
Combined Cycle Gas	2,000	
Hydro	4,200	
Open Cycle Gas	10,500	
Wind	3,500	
Solar PV	323	
Pump Storage	0	2
Battery Storage	100	0.06

Table 1 - Generator Mix in Current NEM Energy output

		Carbon Intensity	0.83	Tonnes CO2/MWh	
Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$ 55.00	$ 64.69	$ 78.83	$ 86.03
SLCOE	$/MWh	$ 59.01	$ 68.73	$ 83.00	$ 90.06
Domestic Retail	$/MWh	$201.00	$210.98	$225.11	$232.31
Abatement Cost	$/Tonne CO2	NA	NA	NA	NA



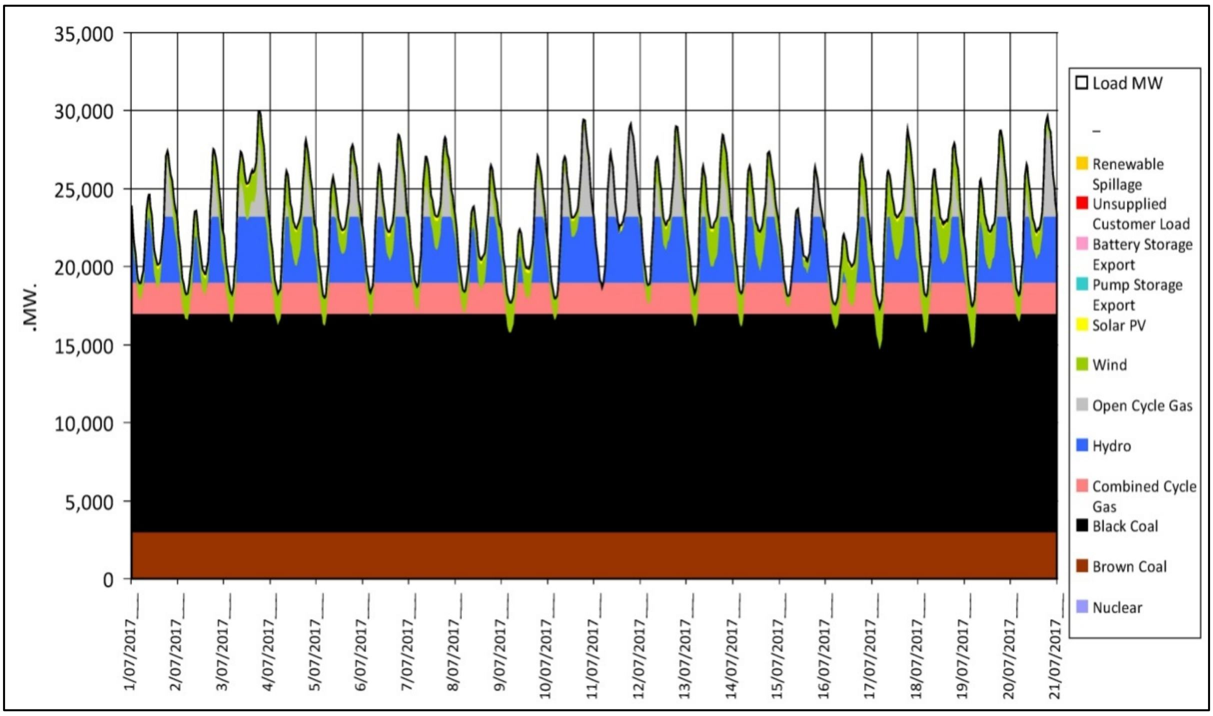


Figure 6 - Current Base NEM Energy Mix in 2017

Electric Power Consulting Pty Ltd
Power System Generation Mix Model Output

Scenario: Base as per NEM 10% — Version 1.6 — Run Number 525

Generation Type	Installed MW	Net Available MW	Storage Days	% of Load Energy Suppied	Levelised Cost of Energy (LCOE) $/MWh	Contribution to System Levelised Cost of Energy (SLCOE) $/MWh	Carbon Intensity T/MWh	Contribution to System Carbon Intensity T/MWh
Battery Storage	100	100	0.06	0.0%		$0.16		
Solar PV	323	323		0.4%	$133.46	$0.54	0.034	0.00
Wind	3,500	3,500		5.2%	$109.55	$5.65	0.012	0.00
Open Cycle Gas	10,660	10,500		1.7%	$441.43	$7.61	0.606	0.01
Hydro	4,200	4,200		8.0%	$113.17	$9.10	0.024	0.00
Combined Cycle Gas	2,116	2,000		7.0%	$98.91	$6.90	0.415	0.03
Black Coal Supercritical	14,815	14,000		63.9%	$61.49	$39.27	0.9635	0.62
Brown Coal Supercritical	3,175	3,000		13.8%	$69.37	$9.59	1.228	0.17
Total	38,889	37,623 MW					Total.....	0.83

Energy storage decrease 0.0%

Total..... 100.0%

Subtotal Generation.....	$78.83 /MWh
Extra Transmission...	$4.04 /MWh
System Levelised Cost of Energy	$82.86 /MWh
Base Transmission.....	$42.25 /MWh
Delivered Cost of Energy for Transmission Customers	$125.11 /MWh
Distribution...	$100.00 /MWh
Delivered Cost of Energy for small LV Customers	$225.11 /MWh

CO2 Emission Abatement Analysis

Reference Base level.... $68.73/MWh 0.83 T/MWh

Cost of Abatement N/A /Tonne

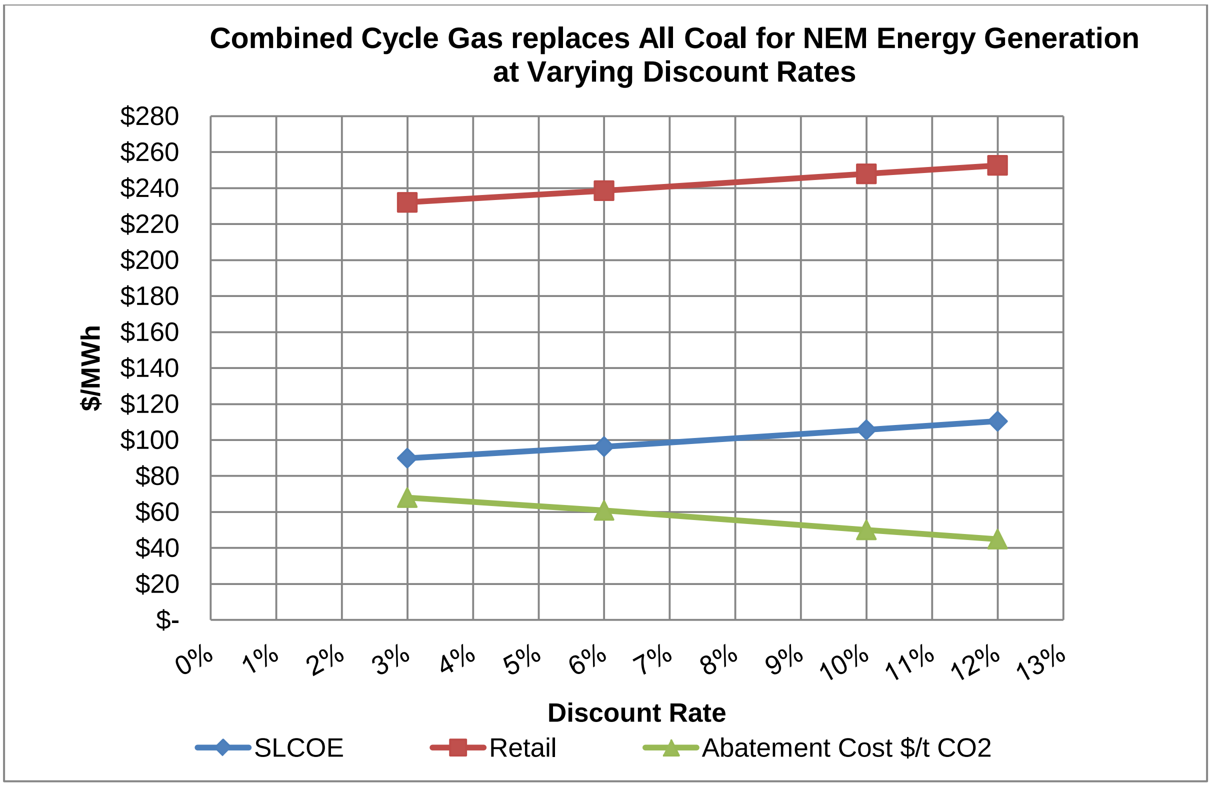
Figure 7 - EPC model output for current NEM Energy mix 2017

CASE 2 - ALL COAL REPLACED WITH COMBINED CYCLE GAS

GenTypeDesc	Installed MW	Storage Days
Nuclear	0	
Brown Coal Supercritical	0	
Black Coal Supercritical	0	
Combined Cycle Gas	18000	
Hydro	3,000	
Open Cycle Gas	6,450	
Wind	0	
Solar PV	4,000	
Pump Storage	3,000	2
Battery Storage	100	0.06

Table 2 - Generator mix with All Coal replaced by Combined Cycle gas

	Carbon Intensity		**0.373**	**Tonnes CO2/MWh**	
Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$ 87.13	$ 93.63	$102.98	$107.72
SLCOE	$/MWh	$ 89.84	$ 96.35	$105.70	$110.43
Domestic Retail	$/MWh	$232.09	$238.60	$247.95	$252.68
Abatement Cost	$/Tonne CO2	$ 68.02	$ 60.92	$ 50.08	$ 44.95



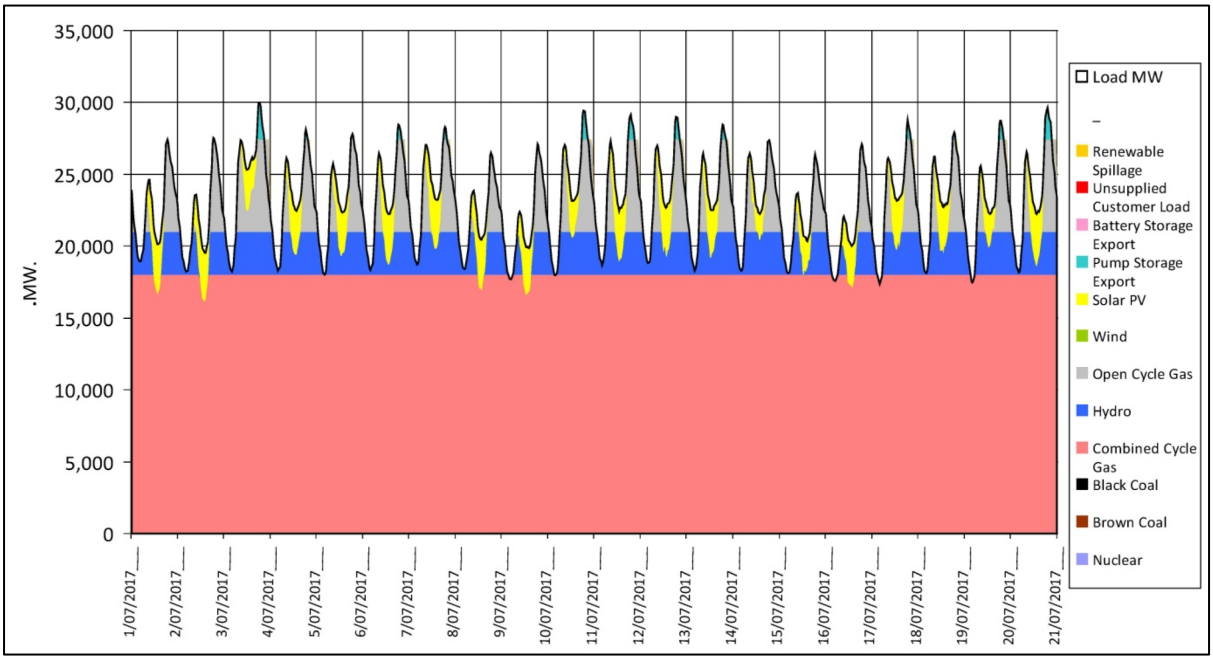


Figure 8 Combined Cycle Gas replaces All Coal Generator Mix on NEM

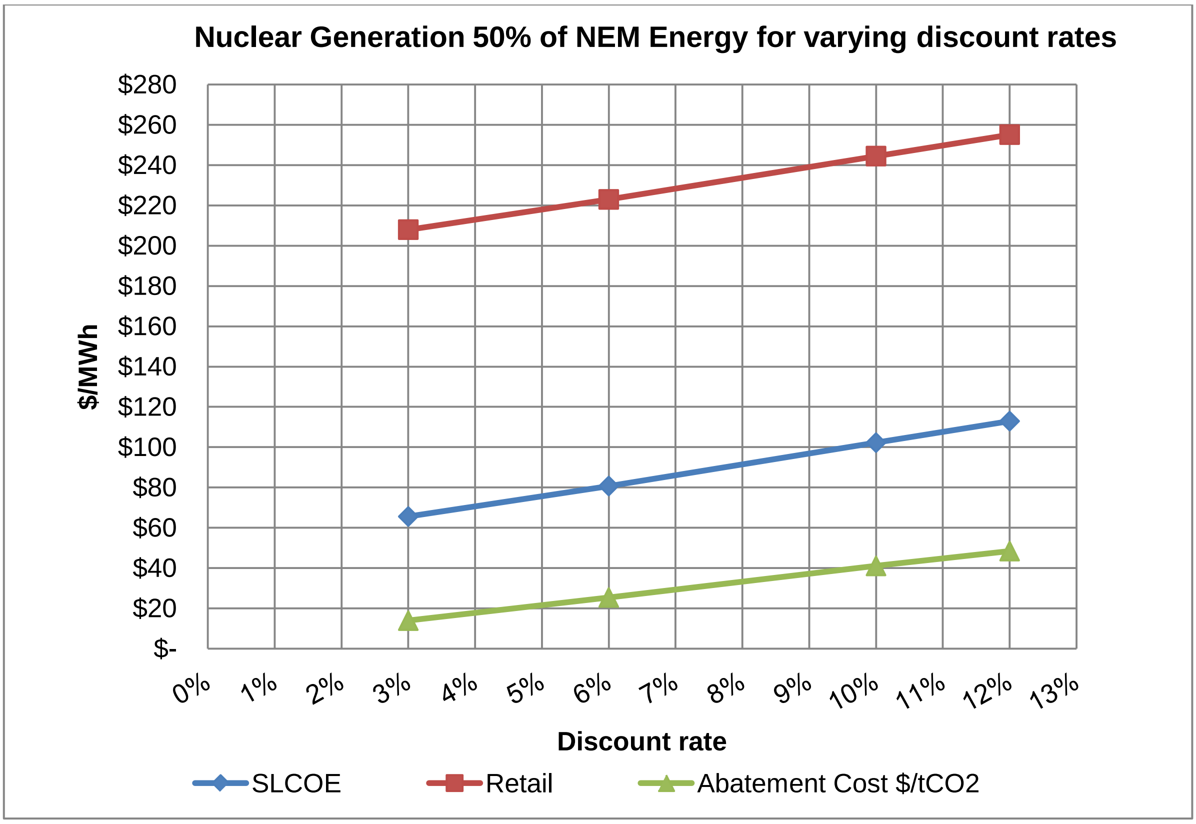
CASE 3 - NUCLEAR POWERED ELECTRICITY GENERATION - 50% OF NEM ENERGY

GenTypeDesc	Installed MW	Storage Days
Nuclear	10,800	
Brown Coal Supercritical	1,200	
Black Coal Supercritical	5,600	
Combined Cycle Gas	800	
Hydro	3,400	
Open Cycle Gas	8,000	
Wind	1,400	
Solar PV	2,500	
Pump Storage	3,000	2
Battery Storage	100	0.06

Table 3 - Generator Mix for 50% Nuclear Energy on the NEM

Carbon Intensity 0.35 Tonnes CO2/MWh

Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$ 62.55	$ 78.00	$ 99.23	$109.91
SLCOE	$/MWh	$ 65.58	$ 80.72	$102.26	$112.93
Domestic Retail	$/MWh	$208.00	$223.00	$244.51	$255.18
Abatement Cost	$/Tonne CO2	$ 13.90	$ 25.39	$ 41.06	$ 48.41



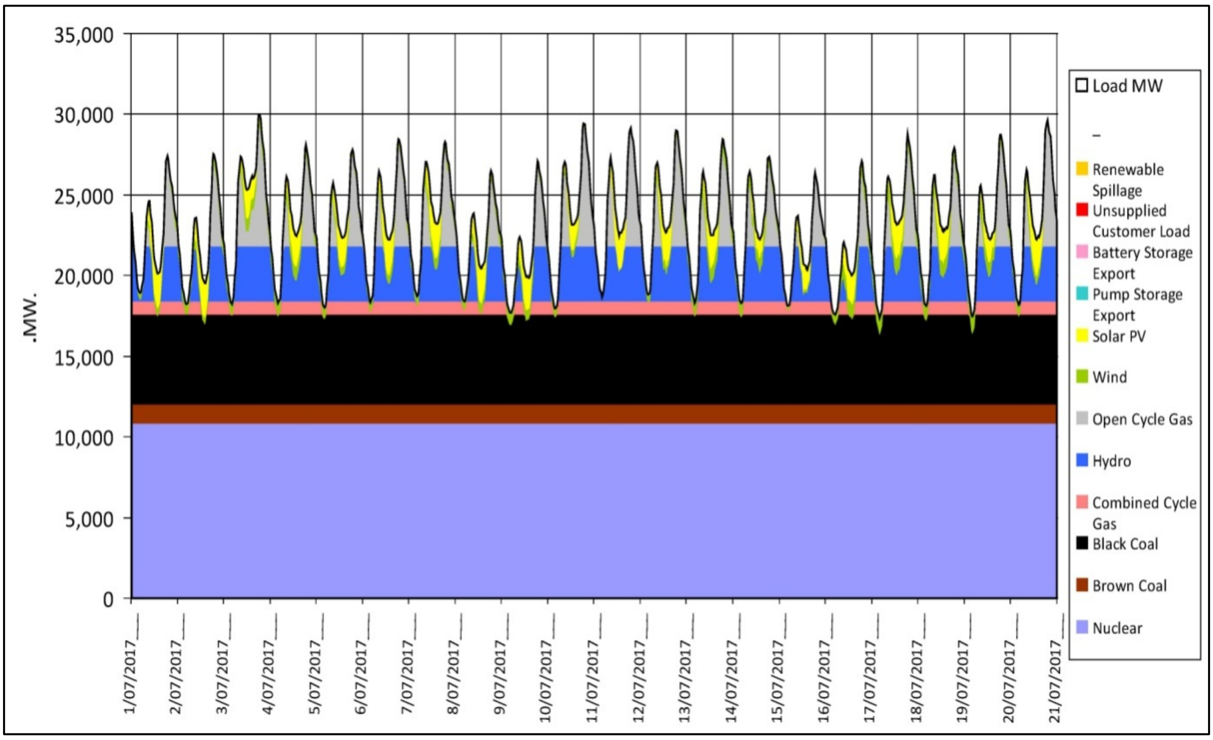


Figure 9 - Nuclear Power Generation 50% of NEM Energy

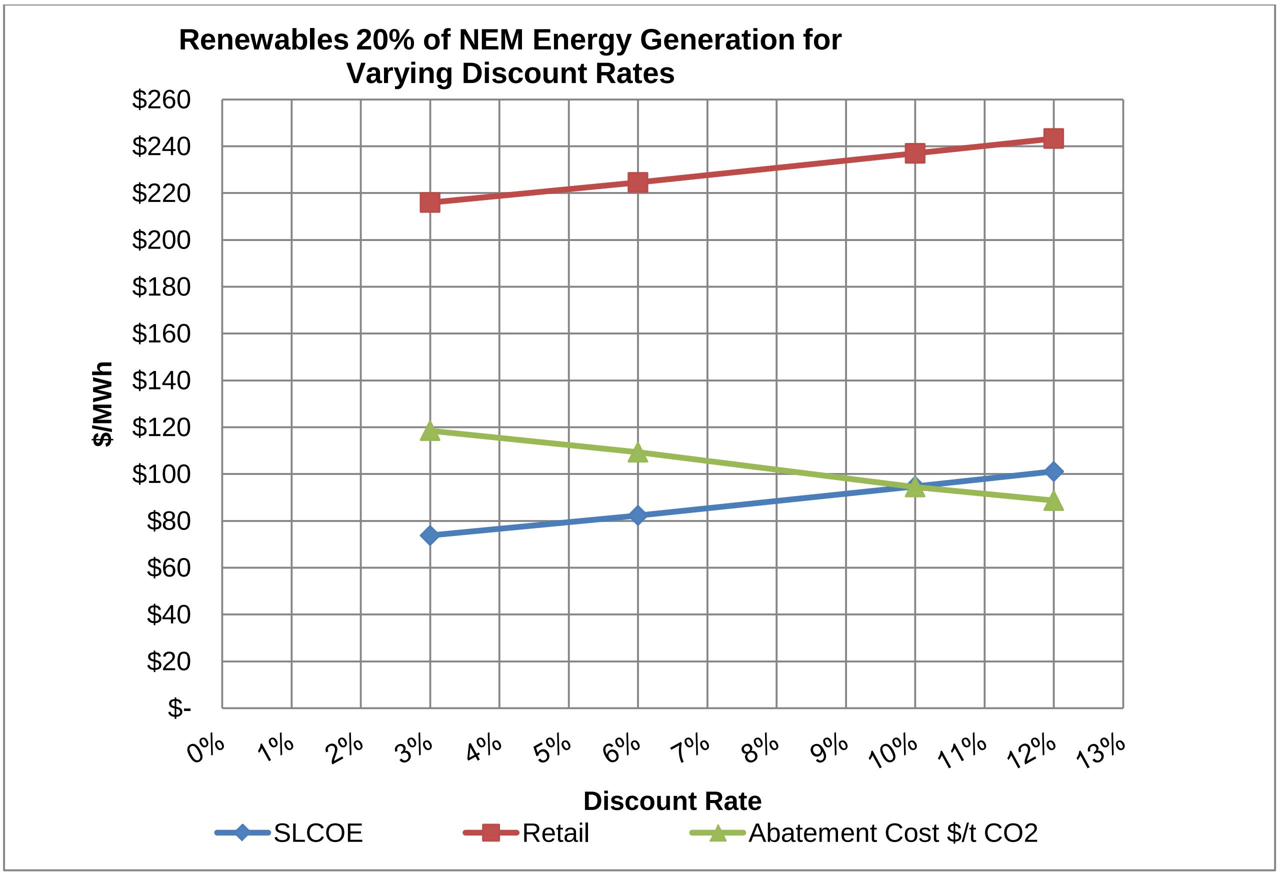
CASE 4 - RENEWABLE ELECTRICITY GENERATION - 20% OF NEM ENERGY

GenTypeDesc	Installed MW	Storage Days
Nuclear	0	
Brown Coal Supercritical	2,500	
Black Coal Supercritical	9,750	
Combined Cycle Gas	2,000	
Hydro	2,200	
Open Cycle Gas	13,800	
Wind	3,000	
Solar PV	5,500	
Pump Storage	1,500	2
Battery Storage	100	0.06

Table 4 - Generator Mix for 20% Renewable Energy on the NEM

Carbon Intensity **0.7 Tonnes CO2/MWh**

Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$ 66.37	$ 74.94	$ 87.36	$ 93.70
SLCOE	$/MWh	$ 73.76	$ 82.33	$ 94.75	$101.09
Domestic Retail	$/MWh	$216.01	$224.58	$237.00	$243.34
Abatement Cost	$/Tonne CO2	$118.55	$109.34	$ 94.48	$ 88.67



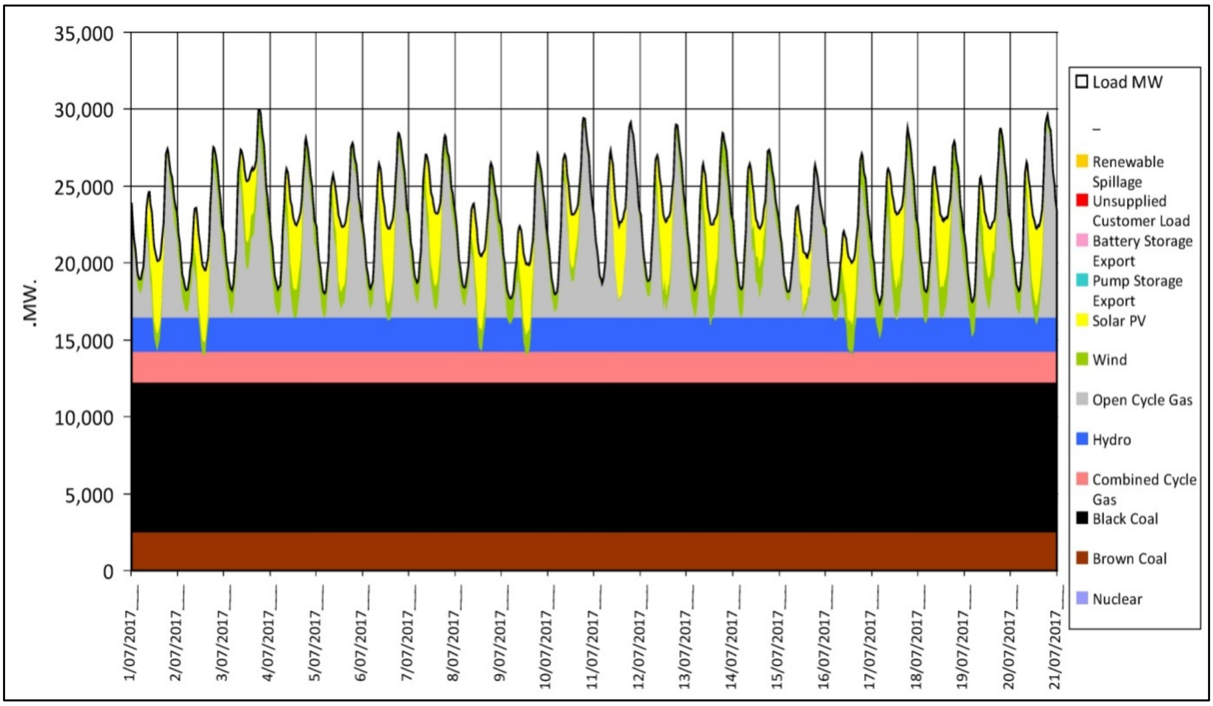


Figure 10 - Renewables 20% of NEM Energy Generation

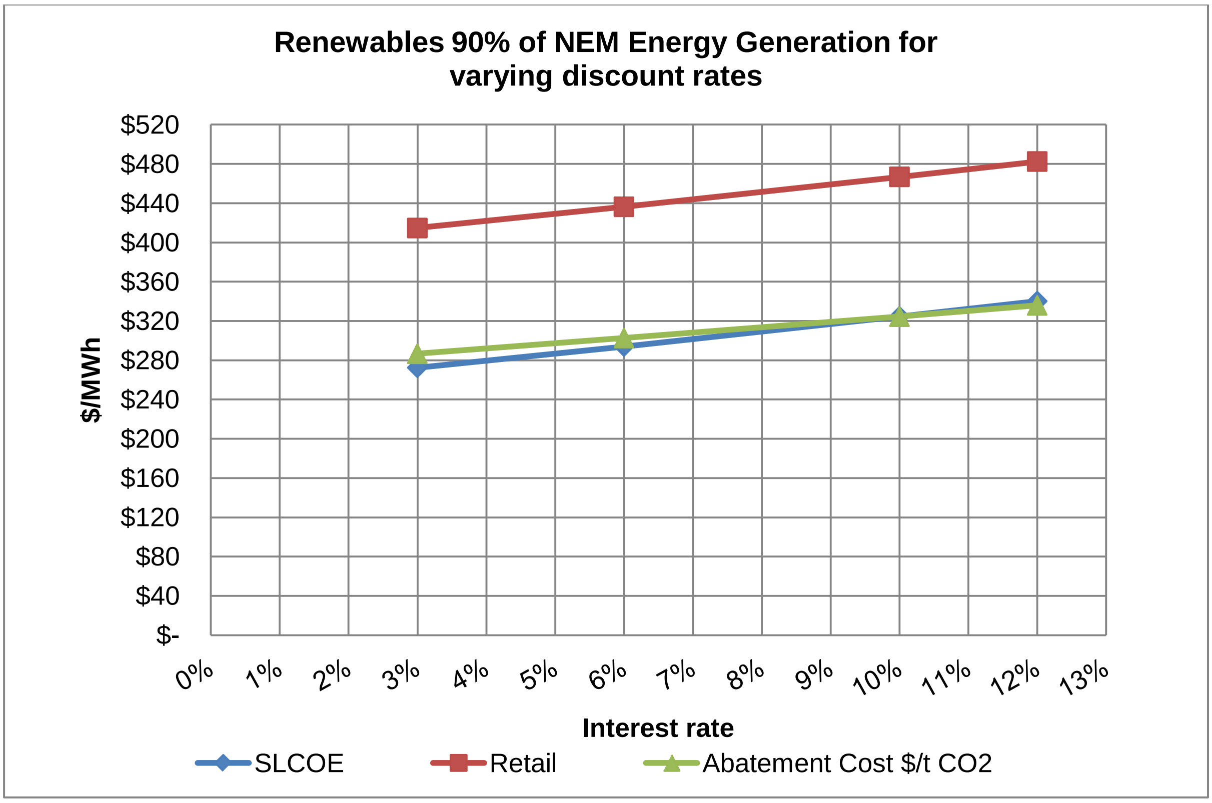
CASE 5- RENEWABLE ELECTRICITY GENERATION - 90% OF NEM ENERGY

GenTypeDesc	Installed MW	Storage Days
Nuclear	0	
Brown Coal Supercritical	0	
Black Coal Supercritical	0	
Combined Cycle Gas	0	
Hydro	4,800	
Open Cycle Gas	18,000	
Wind	50,000	
Solar PV	55,000	
Pump Storage	5,000	2
Battery Storage	100	0.06

Table 5 - Generator Mix for 90% Renewable Energy on the NEM

Carbon Intensity **0.08 Tonnes CO2/MWh**

Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$151.19	$172.81	$203.33	$218.92
SLCOE	$/MWh	$272.44	$294.06	$324.58	$340.18
Domestic Retail	$/MWh	$414.69	$436.31	$466.83	$482.43
Abatement Cost	$/Tonne CO2	$286.60	$302.58	$324.40	$335.86



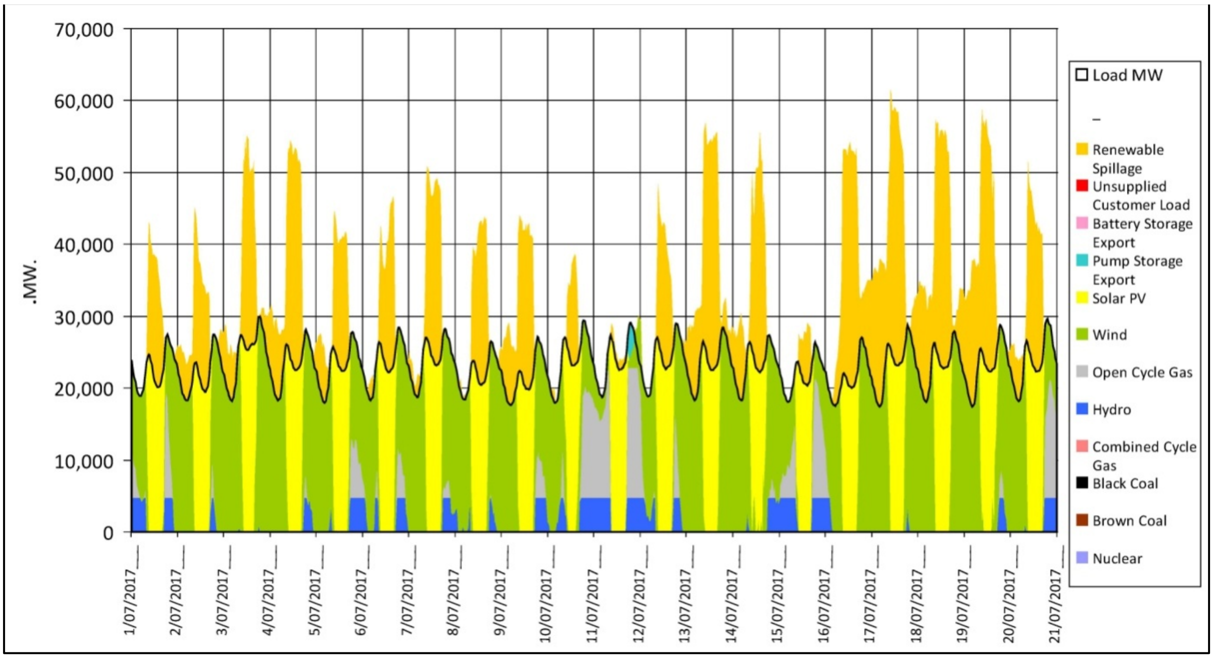


Figure 11 Renewables Generation at 90% of NEM Energy

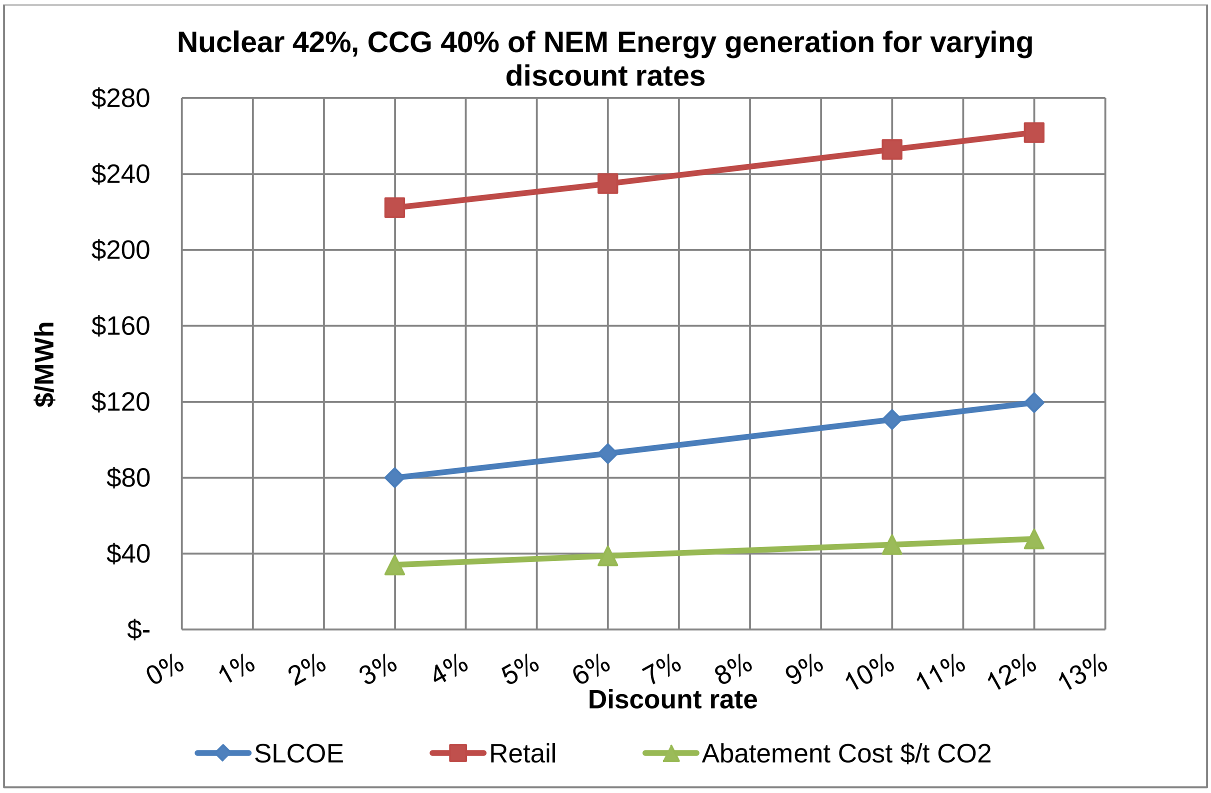
CASE 6 - NUCLEAR POWER 42% COMBINED CYCLE GAS 40% OF NEM ENERGY

GenTypeDesc	Installed MW	Storage Days
Nuclear	9,000	
Brown Coal Supercritical	0	
Black Coal Supercritical	0	
Combined Cycle Gas	9,000	
Hydro	3,000	
Open Cycle Gas	6,450	
Wind	0	
Solar PV	4,000	
Pump Storage	5,000	2
Battery Storage	100	0.06

Table 6 - Generator Mix for 42% Nuclear and 40% Combined Cycle Gas Energy on the NEM

Carbon Intensity **0.21 Tonnes CO2/MWh**

Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$ 77.33	$ 90.00	$107.97	$116.86
SLCOE	$/MWh	$ 80.05	$ 92.72	$110.69	$119.58
Domestic Retail	$/MWh	$222.30	$234.97	$252.94	$261.83
Abatement Cost	$/Tonne CO2	$34.07	$38.86	$44.83	$47.79



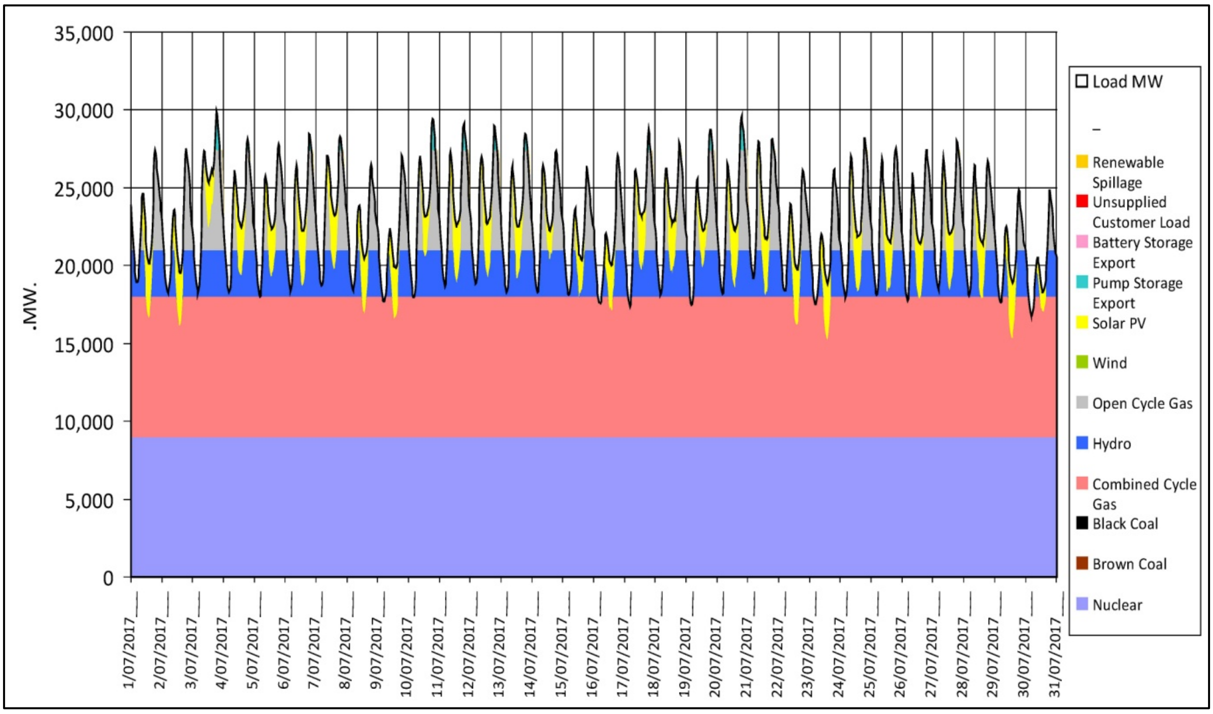


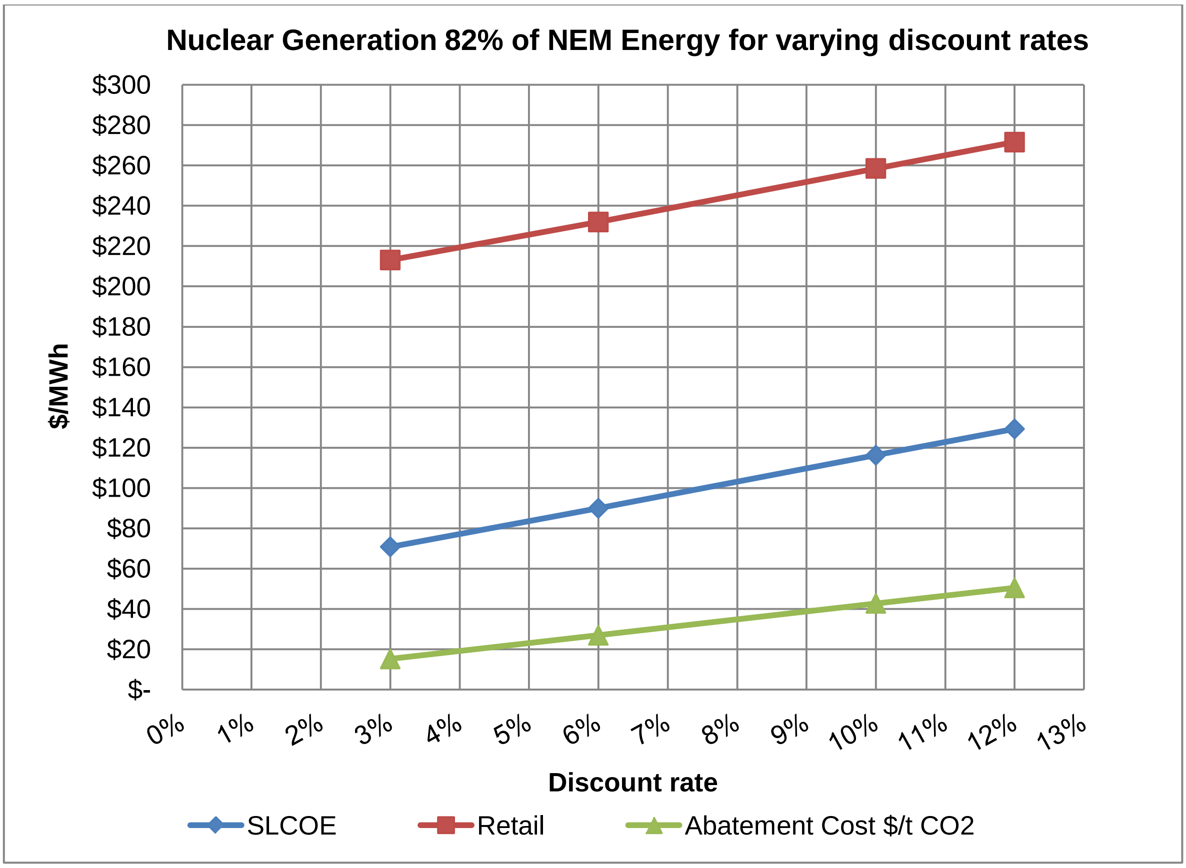
Figure 12 - Total NEM Energy with 42% Nuclear and 40% combined Cycle Gas

CASE 7 - NUCLEAR POWERED ELECTRICITY GENERATION - 82% OF NEM ENERGY

GenTypeDesc	Installed MW	Storage Days
Nuclear	18,000	
Brown Coal Supercritical	0	
Black Coal Supercritical	0	
Combined Cycle Gas	0	
Hydro	3,000	
Open Cycle Gas	6,450	
Wind		
Solar PV	4,000	
Pump Storage	5,000	2
Battery Storage	100	0.06

Table 7 - Generator mix for 82% of Nuclear Energy on the NEM

	Carbon Intensity			**0.05**	**Tonnes CO2/MWh**
Parameter	Discount	3.00%	6%	10%	12.00%
Generation	$/MWh	$ 68.13	$ 86.97	$113.55	$126.59
SLCOE	$/MWh	$ 70.85	$ 89.96	$116.27	$129.31
Domestic Retail	$/MWh	$213.10	$231.94	$258.52	$271.56
Abatement Cost	$/Tonne CO2	$ 15.22	$ 26.96	$ 42.79	$ 50.49



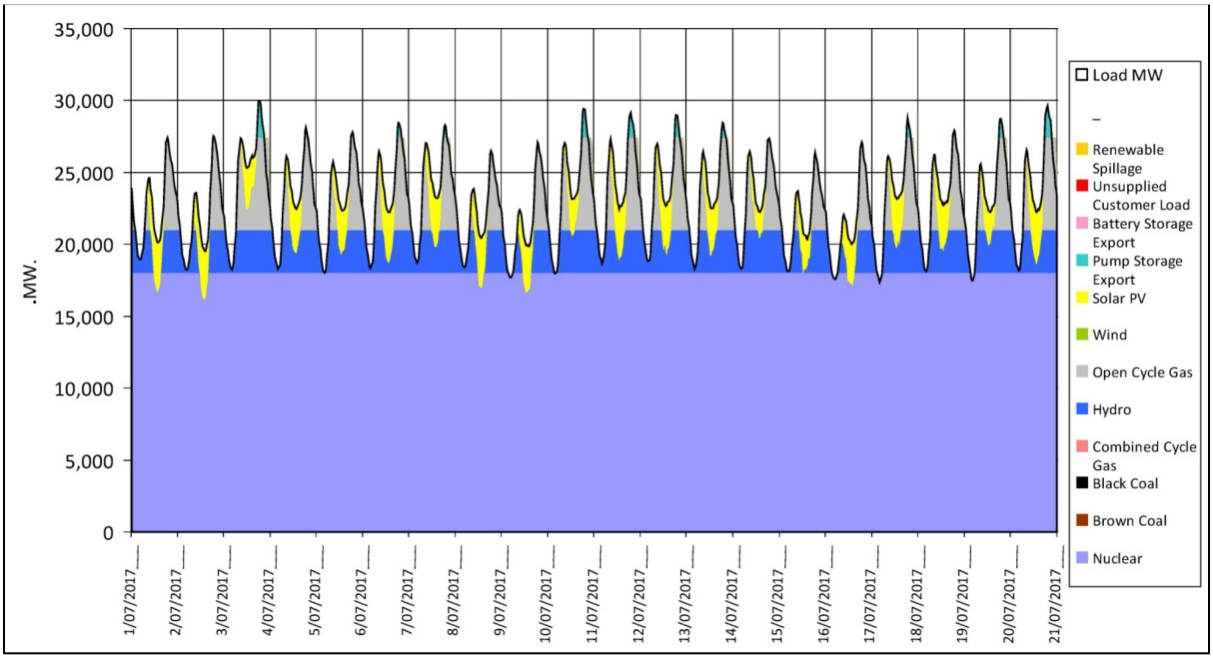


Figure 13 - Nuclear Power Generation 82% of NEM Energy

APPENDIX 2 - VITAL STATISTICS OF NUCLEAR GENERATION VS. RENEWABLES GENERATION ON THE NEM

The following five graphs show the comparison of:

1. **System Levelised Cost of Electricity** (SLCOE) being the final system cost which incorporates all the types of generation in the mix. The commonly quoted Levelised Cost of Electricity (LCOE) is frequently thought of as being a constant value. It is not. The LCOE varies according to how much time the output of a generator actually contributes to the system and of course, how much of its energy is either curtailed or wasted. The output from the model developed by Dr Robert Barr fully accounts for the varying LCOE of each generator and adds an allowance for additional transmission to produce a final system cost or SLCOE.
2. **Retail Electricity**. This graph compares the final cost of the power at the wall for domestic and commercial customers on the NEM. A separate data base exist for Energy for large scale transmission customers such a aluminium smelters however in the interests of brevity this has not been included in this paper but is available for discussion.
3. **Carbon Abatement**. The three aims of our energy renewal are to achieve low cost, reliability and low carbon emissions. The final graph shows the vastly lower cost of carbon abatement (reduction) in terms of A$/tonne of carbon dioxide obtainable from nuclear energy compared to renewables. This performance is verified each day in France, Sweden, South Korea and Switzerland.
4. Selected Energy options ranked by retail price to small low voltage consumers
5. Selected Energy options ranked by Abatement Cost

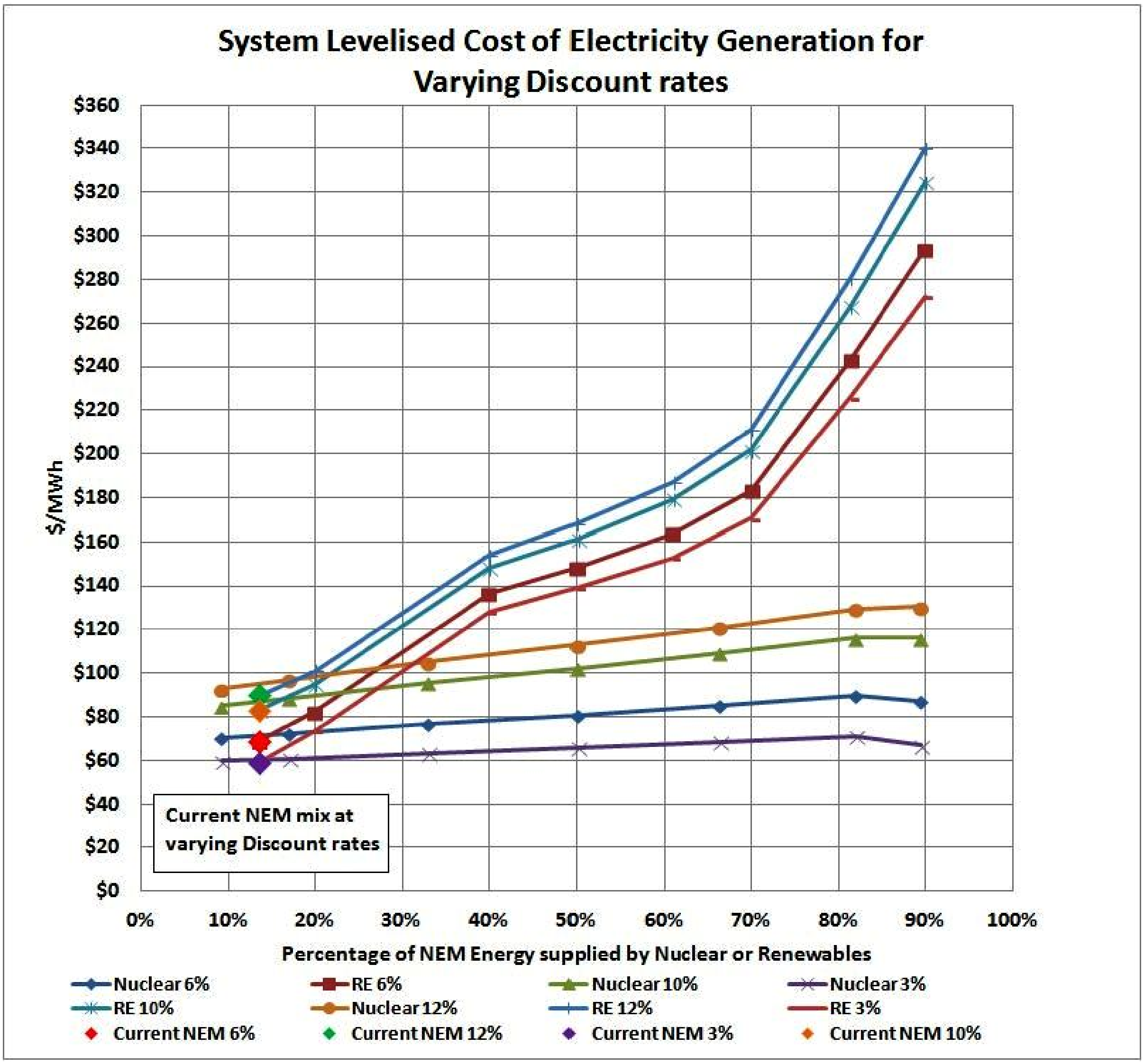


Figure 14 - System Levelised Cost of Electricity Generation,

Nuclear compared to Renewables at varying discount rates

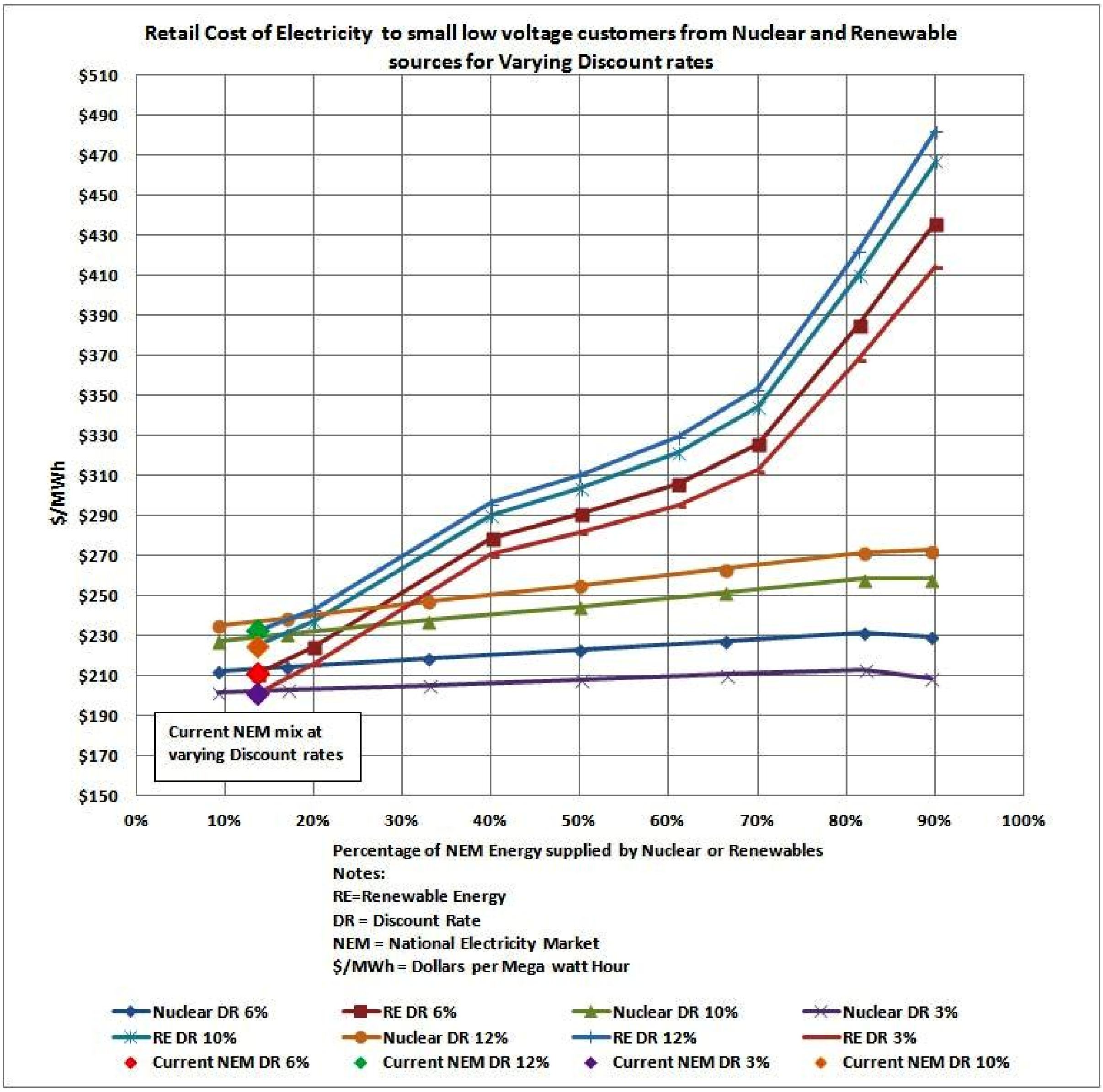


Figure 15 - Comparison of Retail costs of electricity for small, low voltage customers, Nuclear vs Renewables

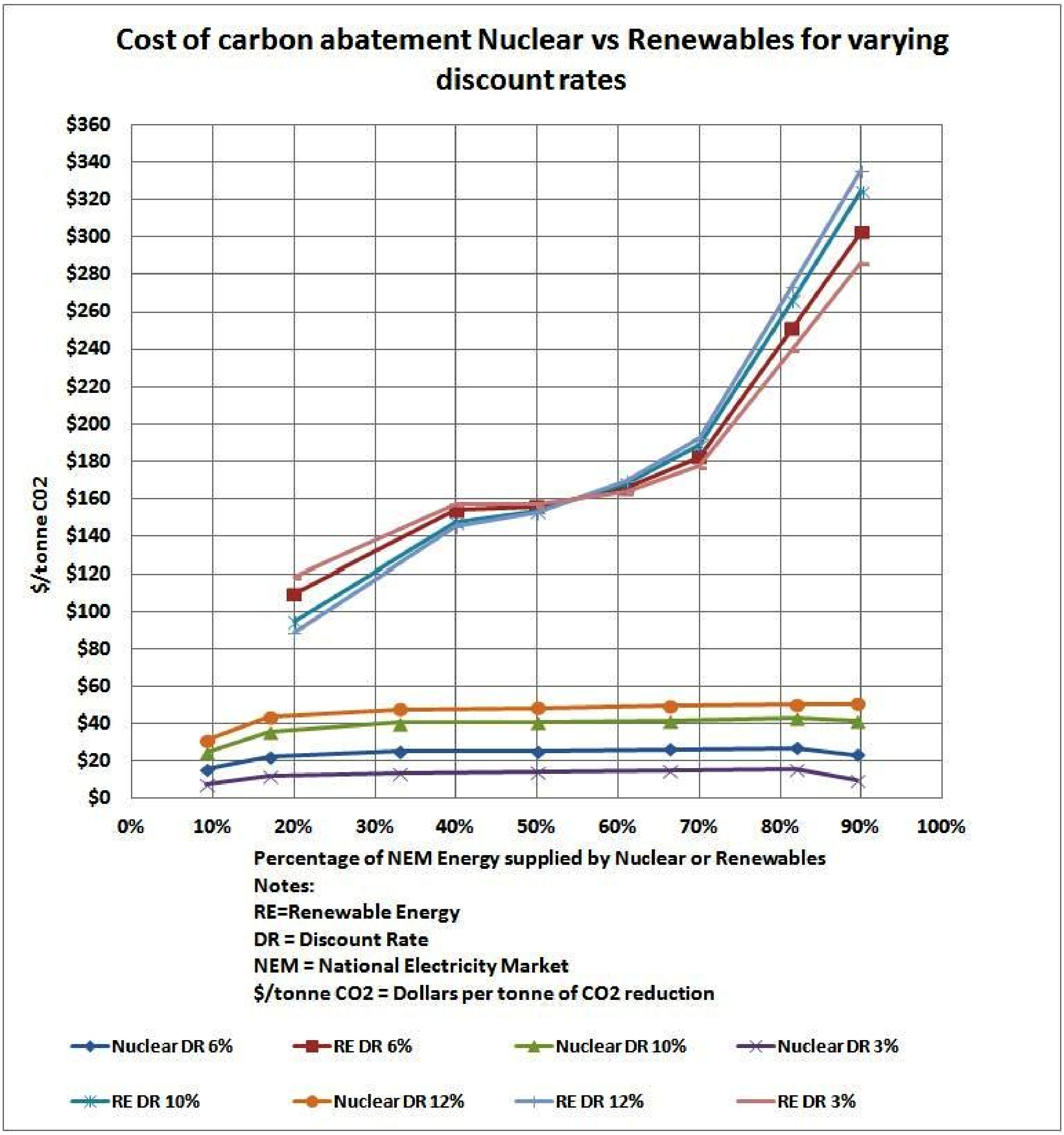


Figure 16 - Comparison of Nuclear and Renewable Energy Carbon Abatement costs at varying discount rates.

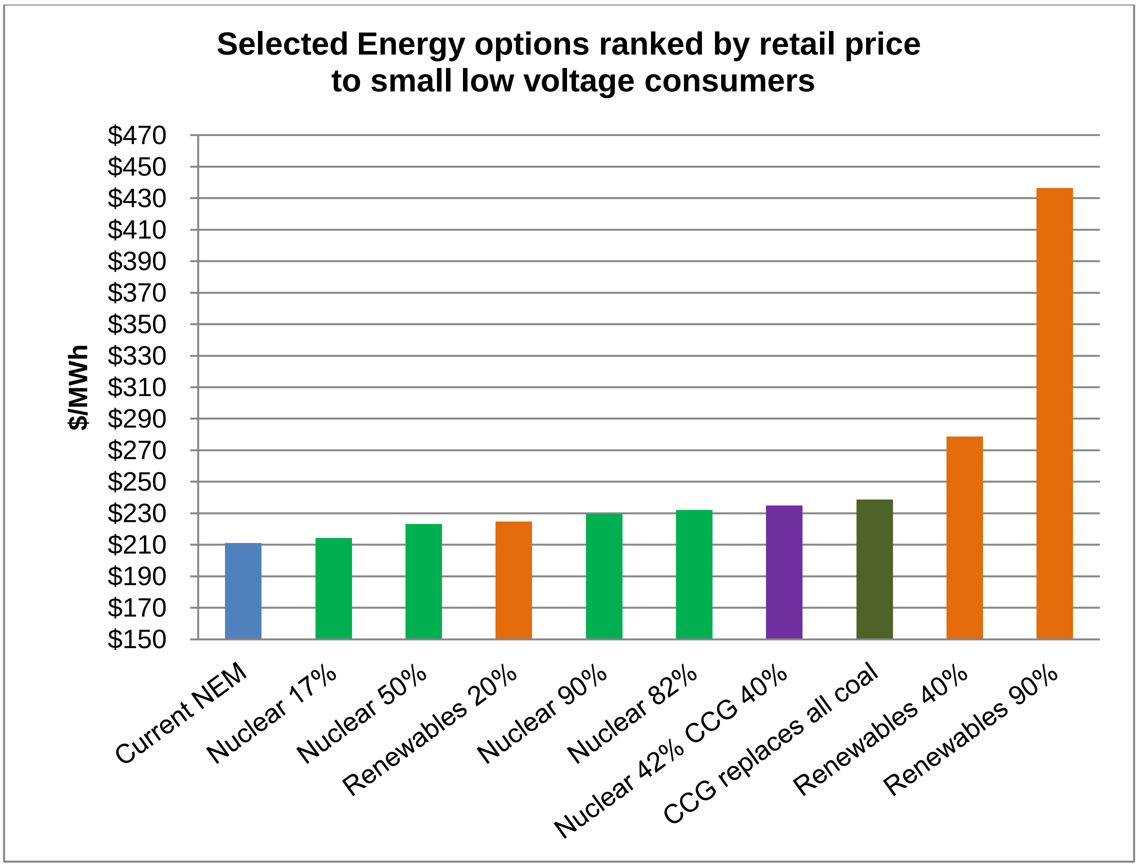


Figure 17 - Selected Generating options ranked on Retail price

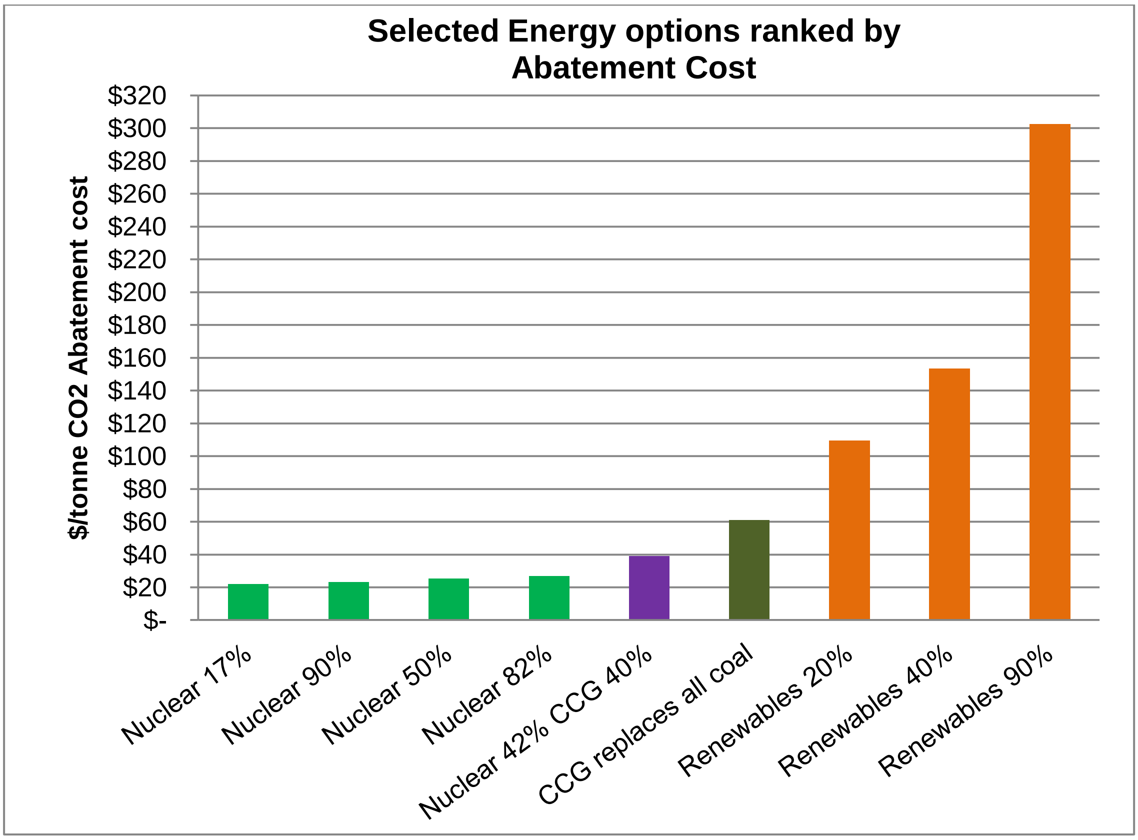


Figure 18 - Selected generating Options ranked on carbon abatement cost