The Effect of Renewable Energy Targets on the National Energy Market

2018

Gamma Energy Technology
EXPERIENCE THINKING INNOVATION

REDVector

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How to reference this report:

Boston, A., Bongers, G., and Byrom, S. (2018), *The Effect of Renewable Energy Targets on the National Energy Market,* Gamma Energy Technology P/L, Brisbane Australia.

Financial Support:

The authors wish to acknowledge financial assistance provided through Australian National Low Emissions Coal Research and Development (ANLEC R&D). ANLEC R&D is supported by Australian Coal Association Low Emissions Technology Limited and the Australian Government through the Clean Energy Initiative.

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Red Vector is a UK Limited Company that provides an energy consulting service based on Andy Boston's 30 years experience in the energy industry starting with the nationalised CEGB, through privatisation firstly with PowerGen and thence E.ON, and finally with the Energy Research Partnership.

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Gamma Energy Technology P/L is an independent energy consulting service, offering a range of technical and support services, including but not limited to power generation technology.

Gamma Energy Technology P/L is proud to contribute to the on-going discussions on energy in Australia as we seek to solve the trilemma of energy supply - to assure energy system security and affordability so that emissions reduction targets are delivered.

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Executive Summary

Most Australian states and territories have relied on coal fired power generation for over 80% of their electricity supplies. More recently, Queensland, Victoria, South Australia and ACT have adopted policies to substantively increase sourcing their electricity from renewable energy and targeting net zero emissions aspirations for the future. The state and territory policy positions are broadly consistent, with a minimum renewable energy target specified and aspire to net zero emissions by 2050 at the latest.

How this impacts on the physical operation of the National Energy Market (NEM) has been examined in this work, an extension of the 2017 study, Managing Flexibility Whilst Decarbonising Electricity: the Australian NEM is changing.[1] In particular, the impact of the Queensland and Victorian renewable energy targets (QRET and VRET) has been modelled using MEGS which takes account of the enduring need for grid strength and reliability services.

The broad conclusions of this work are summarised as follows:

QRET & VRET combined achieves neither Finkel 2030 nor electricity's emissions reduction contribution to Paris

- The RETs modelled achieve only half of the required abatement for the electricity sector to meet the Paris Agreement
- Pursuing renewable targets significantly beyond these will decrease effectiveness of solar and wind, as the market saturates and output is curtailed
- Previous modelling has already shown that decarbonisation beyond 40% will need new unabated gas and CCS
- CCS will need to be ready to provide reliable, low emissions, grid supporting electricity in the early 2030's
- Impact of VRET is felt beyond the state boundary
    - Much of new renewable generation is exported to surrounding states, putting downward pressure on wholesale prices
- Impact of QRET does not build as many renewable plants as the headline 50% target might suggest
    - Only half of this target requires new build, effects are mostly absorbed within Queensland

There are significant NEM wide impacts for coal plant

- QRET+VRET do not force any more shutdown cycles than the base case
    - However, there is a significant amount of load following for coal required, pushing up costs, and reducing output
- Investment will be required to facilitate these plants having this capability

[1] Boston, A. Bongers, G, Byrom, S and Staffell, I. (2017). *Managing Flexibility Whilst Decarbonising Electricity – the Australian NEM is changing.* Gamma Energy Technology P/L, Brisbane, Australia.

There is downward pressure on average electricity prices but an upward pressure on volatility

- The RETs increase volatility by suppressing prices during low demand / high renewable output periods
- Any such regulated deterioration of economics of fossil-fuelled plant encourages early closure which will likely raise peak prices

Deep Decarbonisation requires a diverse portfolio of plant

- It is not possible to go beyond 65% decarbonisation with renewables alone without incurring huge uplift costs to the system. In some capex scenarios it makes sense to avoid going beyond even 40% with renewables alone.
- CCS makes a perfect complementary technology for renewables in deep decarbonisation scenarios.
- In addition, there will need to be an element of flexible, low load factor fossil for meeting peaks, providing grid services and supporting the grid in weeks of low renewable production
- Retaining the option for deep decarbonisation requires immediate and continuing investment in the development of CCS, with a strong emphasis on upgrading existing fossil to improve its flexibility to operate in emerging electricity markets

Performance Metrics for Decarbonisation of a Grid

- It is increasingly clear from this study that the "Total System Cost" is the better metric by which to assess the affordability of emissions reduction pathways. Although familiar to many, the Levelised Cost of Electricity (LCOE) would be completely out of the context it was designed for and therefore very misleading when comparing generation options.
- National electricity pricing and energy competitiveness will be a strong function of Total System Cost. The most effective path to a low emissions grid will be to track the "least cost" pathway for transforming the constituent asset portfolio.
- Current Federal and State policy settings drive renewable generation investment. However, in Australia, there are no structural or market mechanisms in place to minimise the Total System Cost and ensure affordability of power. It is recommended that accountability for total system cost is transparently assigned within Australian market and regulatory systems.

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Background

Previous Modelling

The current Australian grid has delivered reliable and secure energy for decades. The majority of electricity in the NEM is provided by coal-fired power generation, a technology that has also delivered the services required for grid stability such as inertia and frequency control. Coal and gas-based technologies have underpinned the energy competitiveness of the Australian economy. However, with increasing penetration of weather dependant, intermittent renewable generation, it is becoming more important to plan for and manage generation asset investment to track close to the least cost and highest reliability path to a low emissions future.

A previous study, sponsored by ANLEC R&D[1], used an innovative modelling approach, MEGS, to examine the Australian NEM. MEGS considered the grid system cost by recognising the importance of firm generation, the cost of balancing the system, and the required flexibility, while on the "pathway" to a lower emissions grid.

Key Points from this study included:

- As well as energy supply, each power generation technology brings with it a different set of grid services such as low emissions, inertia, frequency control, flexibility etc
- The NEM is unique when compared other international grid systems; it consists of 5 State-based grids that are only weakly interconnected
- The characteristics of the NEM plays a significant role in determining the value of an additional asset placed on the system. Each State grid will have unique asset requirements and a material impact on the overall NEM system
- It shows that decisions based on technologies with the lowest LCOE can result in a high cost grid system at deep decarbonisation levels due to misleading nature of this metric

The results highlight that approaches to meet short-term emissions targets (e.g: Paris 2030) can be suboptimal if they ignore the long term. The lowest cost energy supply technologies change as NEM decarbonisation proceeds. For example, at high penetration, renewables become increasingly expensive to the grid.

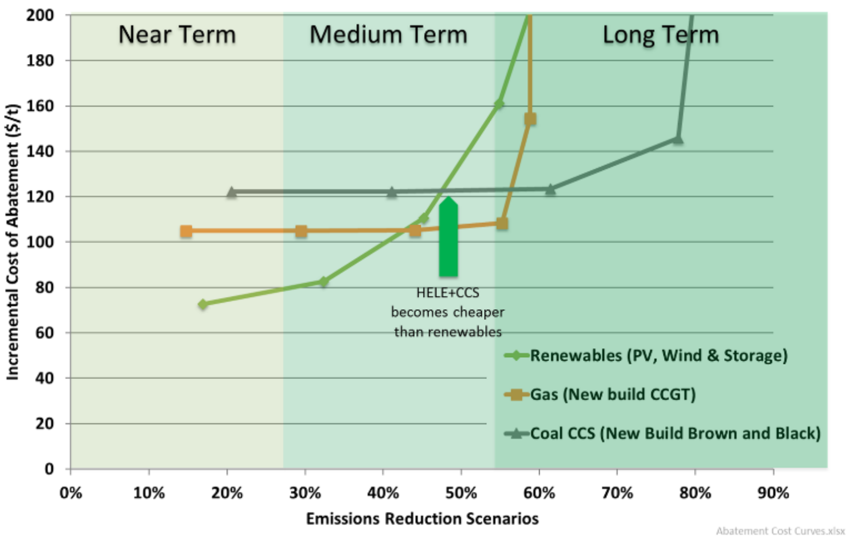


Figure 1: Cost of abatement with increasing emissions reductions from 2017

In Figure 1, renewables costs increase due to intermittency and curtailment. Inflexions for other technologies occur when their emissions limits are reached. At high decarbonisation levels, dispatchable power like coal or gas with carbon capture and storage (CCS) will be required to deliver the required resilience for grid stability**. It can also deliver the deepest decarbonisation ambitions at the lowest cost.**

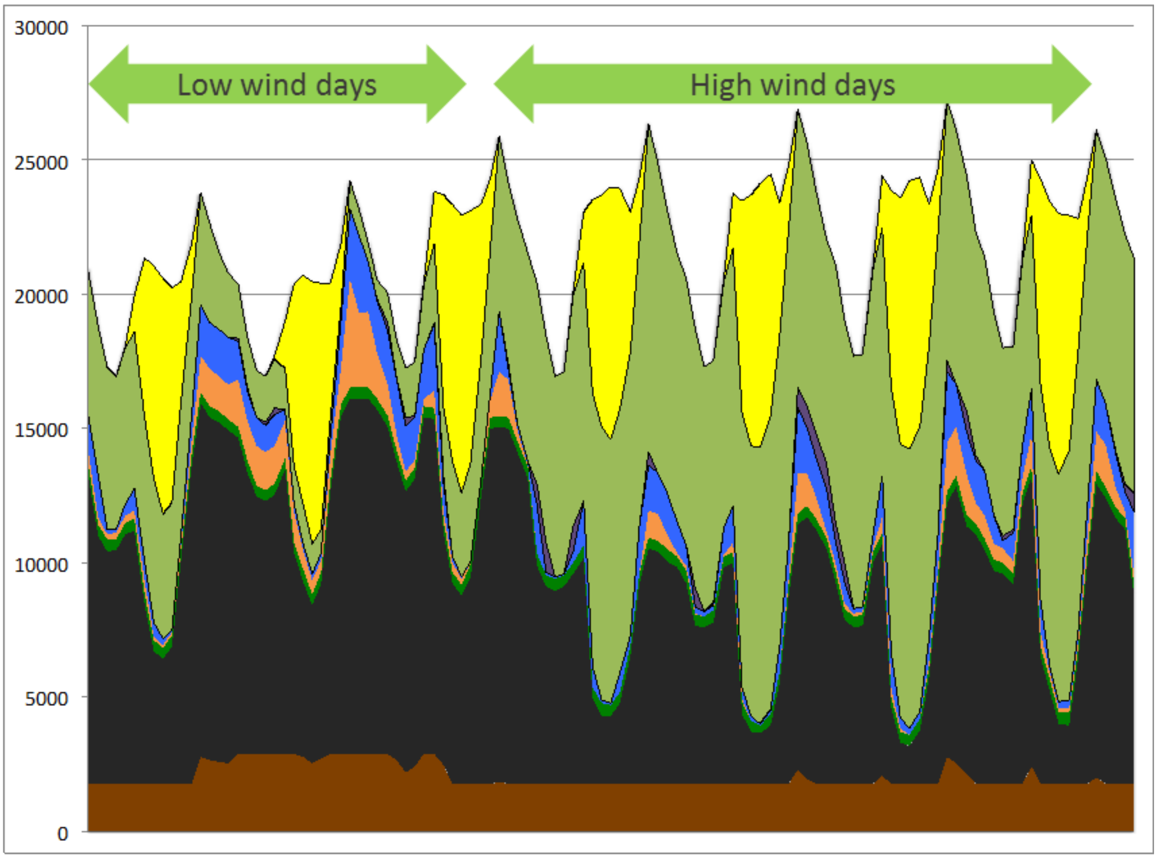


Figure 2: Modelled 7-day generation (high renewables scenario)

High penetrations of wind and solar PV will require companion low carbon technologies if they are to provide firm capacity that is available "on-demand" (refer to Figure 2). In high renewables scenarios, the existing fossil-fuelled power plant (especially black coal) will have to become increasingly flexible on a daily basis.

This is a new operating paradigm for coal assets on the NEM. It requires either new build or investment to upgrade existing plant to ensure they have such flexibility.

Key Terminology / Concepts

The following terms and concepts are defined here for a common understanding of their use within this report

- **Cycling**:
  Range of operations in which a plant's output changes, including starting up and shutting down, ramping up and down, and operating at part-load (less than full output).[2]
- **Forced Outage**:
  An unplanned component failure or other condition that requires the unit be removed from service immediately, within six hours, or before the end of the next weekend.[2]
- **Ramping**:
  Output that varies between full and minimum levels in order to follow changes in demand.[2]
- **Start**:
  Starting of a unit that is offline. Starts are described as hot, warm, or cold, depending on the temperatures of the metal in the turbine.[2]
- **Two Shifting**:
  Operational sequence whereby a generating unit is started and shutdown within a 24-hour period. Typically, the shutdown is overnight. Also used as a general term describing more than one shutdown within a 24-hour period.[2]
- **Wear and Tear**:
  Wear means the component reaches the end of its natural life through ordinary causes, though wear can be accelerated by cycling. Tear refers to an abnormal event that accelerates the life, such as occurs during poor control of operating conditions. While tear may occur during baseload operations, they are more likely during some cycling modes.[2]
- **Frequency control ancillary services (FCAS):**
  Frequency control is critical to power system security, and in the NEM, AEMO is responsible for procuring sufficient frequency control ancillary services (FCAS) to maintain frequency within prescribed operating standards. This task currently relies heavily on the services provided by synchronous generation, although newer technologies (especially storage) are in theory able to provide these services. However, this comes at significant cost if renewable output is curtailed to provide headroom for reserve.[3]
- **Inertia:**
  Inertia is provided by the large rotating masses of all thermal and some hydro generators and turbines. These synchronous machines rotate with the system frequency and their mass resists changes to frequency instantaneously. Inertia could therefore be seen as a store of kinetic energy within the grid itself which is drawn on during a system disturbance. In the past inertia has been abundant in the NEM and it is not directly valued at present, so scarcity is not transparent. However, as conventional plant continues to be displaced by low inertia technologies (intermittent), there are signs of inertia becoming scarce in some parts of the network. Low inertia systems require more FCAS services to be procured and these need to respond on a shorter timescale.[3]

[2] Cochran, J., Lew, D., Nikhil Kumar, N. (2013). *Flexible Coal Evolution from Baseload to Peaking Plant.* National Renewable Energy Laboratory, Colorado, USA. NREL/BR-6A20-60575.
[3] Finkel, A., et al. (2017) *Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future*, Commonwealth of Australia.

The life of a steam turbine and other temperature sensitive components is related to thermal transients experienced over time. Most temperature components have well defined thermal limits and constraints. For a 'sample' steam turbine, Figure 3[4] requires slow temperature changes to manage the thermal stress in their heavy metal components.

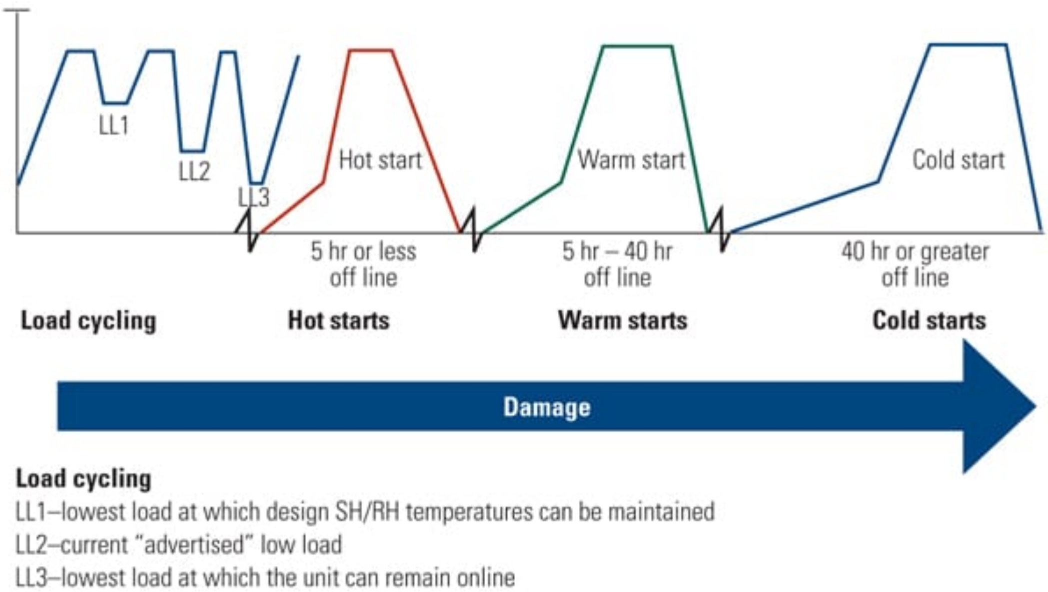


Figure 3: Relative damage caused by cycling steam plants

[4] Lefton, S.A. and Hilleman, D. (2011) *Make Your Plant Ready for Cycling Operations*, available at http://www.powermag.com/make-your-plant-ready-for-cycling-operations

MEGS: Overview and Capabilities

The model at the heart of this work is **MEGS** – **M**odelling **E**nergy and **G**rid **S**ervices. Like many models, it balances energy for each calculated point in time for a grid of interconnected regions, but what makes it unique is its attention to the engineering constraints and ancillary services that ensure a grid is operable. In MEGS, these boil down to ensuring:

- Sufficient fast acting reserve is available to each region,
- A minimum level of inertia is connected in each region, and
- The grid is reliable and operable.

Figure 4 shows how MEGS compares to other modelling techniques.

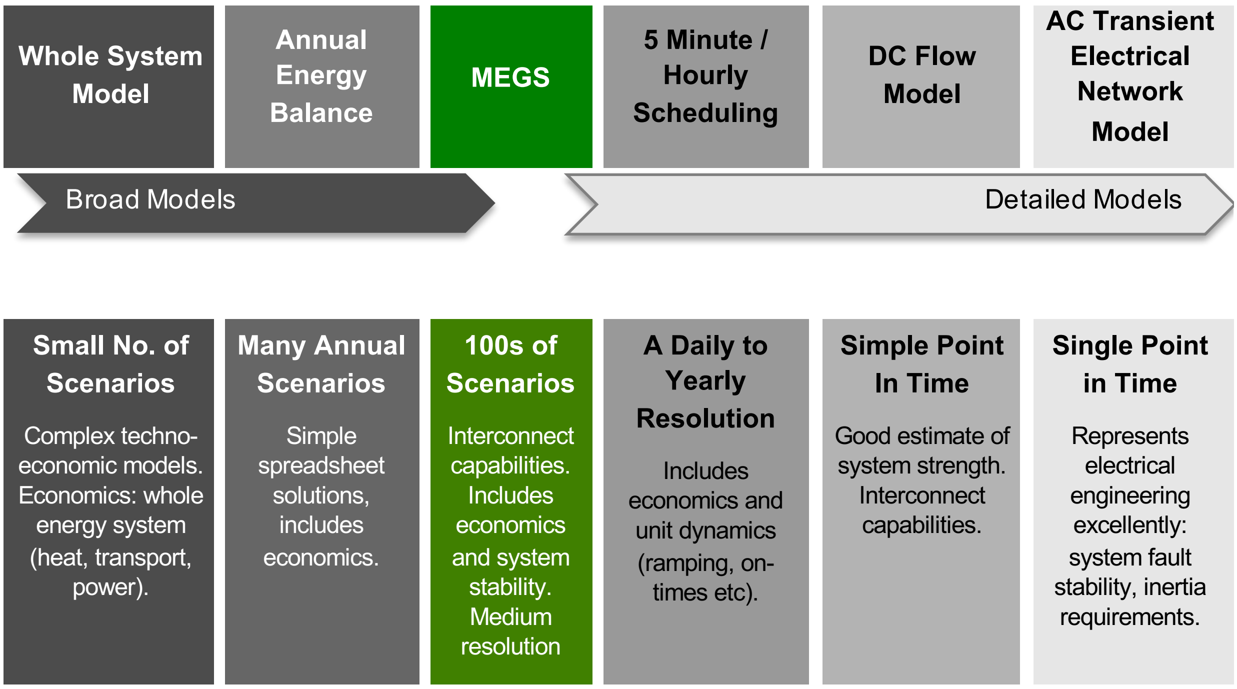


Figure 4: MEGS model in comparison to other methodologies

While MEGS is typically configured to model power plants as aggregated tranches of similar units, it may be configured as an individual plant configuration. For each modelled point in time (typically 2-3 hours apart), the solver determines generation and reserve provision from plant whilst minimising system short run costs which are given by fuel, carbon and non-fuel variable costs.

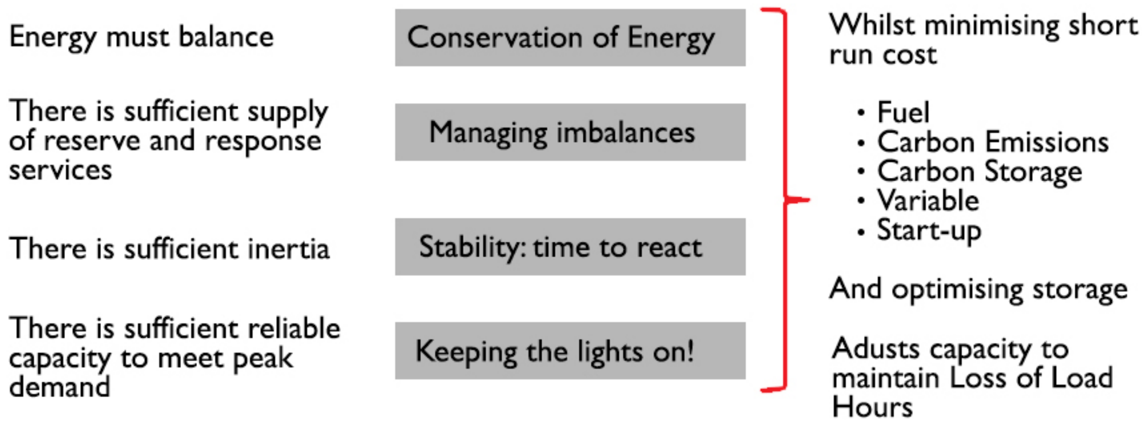


Figure 5: MEGS balances several services essential to grid operation

Forecasting into long term futures is inherently speculative. The ability to explore large uncertainties in future scenarios is an additional MEGS capability. When configured in this format, the model is denoted as **S-MEGS**. S-MEGS can model up to five key uncertainties via a Monte Carlo analysis:

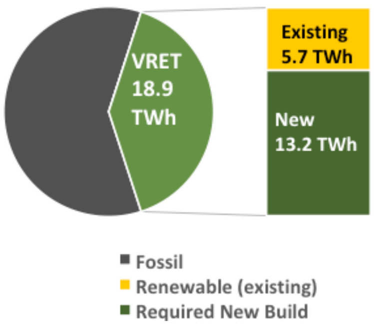
- Weather: chosen from historic data affecting renewables and demand,
- Fuel Prices: chosen annually from a lognormal distribution,
- Capex: chosen annually from a lognormal distribution,
- New Build Projects: large projects are all or nothing, chosen randomly, and
- Clean Tech Build: capacity of renewables or CCS constructed is chosen from a uniform distribution.

For each simulation, a value is chosen for the uncertain parameters from a given distribution. This sets a portfolio of plant with a defined set of costs and historic weather data. A typical S-MEGS run results in 100's of simulations with high-level outputs reported for each one. Viewing a distribution of probabilistic endpoints can be instructive to both recognize patterns that may emerge and highlight the boundaries of an outcome envelope. Although S-MEGS offers a wide range of input parameters which can vary, it is best to limit input variation to the minimum needed to explore the issue in question.

VRET Background

In 2016, the Victorian Government committed to renewable energy generation targets (VRET) of 25% by 2020, 40% by 2025, and a net zero emissions target by 2050. These targets have recently been legislated.[5] To achieve the VRET, a reverse auction scheme will be employed, designed to deliver up to 1,500MW by 2020 and 5,400MW by 2025 of new, large-scale renewable energy projects.

Figure 6 details VRET in terms of renewable generation, both existing and new build generation.

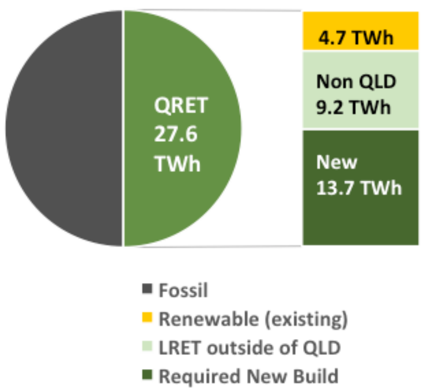


At 420 MW, Macarthur is Australia's largest wind farm. VRET's required new build is equivalent to 10 Macarthur's.

Figure 6: VRET definition - 40% renewable target by generation

QRET Background

In 2016, the Queensland Government commenced an investigation into achieving a 50% renewable energy target in Queensland by 2030. An Expert Panel's report, "Credible pathways to a 50% renewable energy target for Queensland" was delivered in 2017.[5] The report found that Queensland has a high potential to grow its renewable energy industry as a result of decreasing technology costs, market dynamics and a strong pipeline of proposed large-scale renewable projects. The Queensland Government accepted almost all of the recommendations from the Expert Panel.[6] Figure 7 details QRET in terms of renewable generation sources, existing, non-Queensland LRET renewable generation and generation required from new build.



At 102 MW Nyngan is the largest PV farm proposed for Australia. QRET's required new build is equivalent to 60 Nyngan's.

Figure 7: QRET definition - 50% renewable target by generation

[5] Stock, P., Alexander, D., Andrew Stock, A. and Bourne, G. (2017) *Renewables Ready: States Leading the Charge.* Climate Change Council, Victoria, Australia, ISBN: 978-1-925573-28-2.

[6] Department of Energy and Water Supply (2017). *Queensland Government response to the Renewable Energy Expert Panel inquiry into credible pathways to a 50 per cent renewable energy target in Queensland by 2030*. Queensland Government, Australia.

Modelling Q-RET and V-RET

The NEM grid is a composite of 5 State based grids that are weakly interconnected. Many of these States have privatised their electricity businesses and continue to develop their respective environmental performance measures separately. The scenarios modelled in the prior work[1] did not consider the impact of individual State targets and goals, but rather looked at one target for the NEM as a whole.

The aim of this phase of modelling is to examine the effect of fulfilling the various State and Federal Renewable Energy Targets (RETs) examining:

- The decarbonisation of the NEM as a whole,
- The likely evolution of prices across the NEM,
- The effect on NSW (which has no RET of its own),
- The effect on the running regimes of plant directly affected by the RETs, and
- The impact of additional storage as a load and generator.

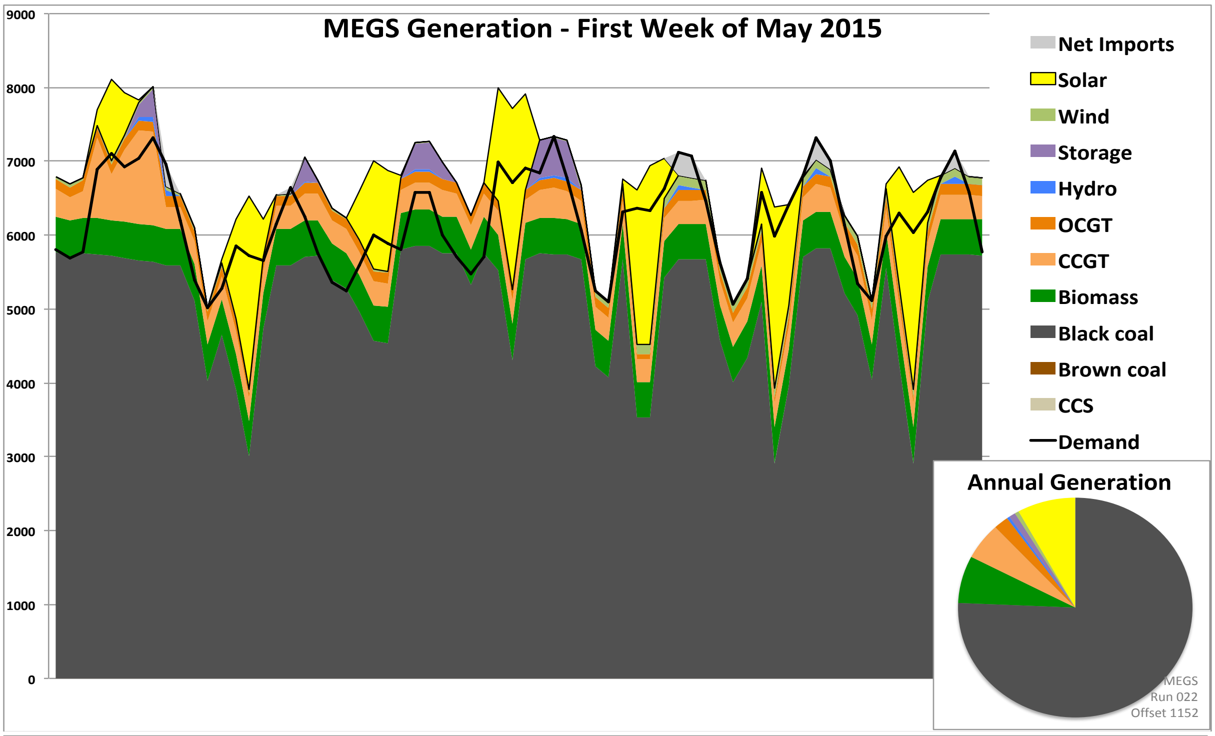
Five scenarios were modelled, one reference case based on 2017 and four combinations of RETs in 2030. This timescale allows the RETs to reach their targets and a comparison with the Finkel study[3] which also focused on this year. The five scenarios were:

1. **Reference**
   2017 reference year.
2. **SRES + LRET (Base)**
   This scenario includes the Federal support for the 33 GWh Large-scale Renewable Energy Target (LRET) across the NEM by 2020. In addition, it is assumed that the Small-scale Renewable Energy Scheme (SRES) continues to support rooftop PV at current installation rate of 750 MW p.a. until 2020, and then at half that rate until 2030 when scheme ends.
3. **Base + QRET**
   This scenario builds on SRES and LRET by adding Queensland's Renewable Energy Target (QRET) where 50% of Queensland's demand met by renewables by 2030.
4. **Base + VRET**
   This scenario builds on SRES and LRET by adding Victoria's Renewable Energy Target (VRET) of 40% of Victoria's demand met by renewables by 2025.
5. **Base + QRET + VRET**
   This scenario combines all the schemes from 2-4 above.

It is important to note that the RETs are not entirely independent. For example, Queensland's Department of Energy and Water Supply (DEWS) has explicitly stated[6] that QRET "includes Queensland's pro-rata share of renewable energy generation under the LRET." Given that little LRET supported plant has been built in Queensland, this means that a considerable proportion (about 28%) of LRET plant in the other 4 States is considered by Queensland to count towards its own target. As QRET is not completely additive to the Queensland grid, it allows for double accounting of renewable output (refer to Figure 7 for more detail on QRET). In fact, renewable energy output in Victoria may also count towards VRET meaning some of this could end up being triple accounted.

Q-RET

The impact of both LRET and SRES (the Commonwealth RETs) on the operation of the Queensland grid is shown Figure 8 as the upper sequence for a sample week based on the weather of May 2015. That base case, combined with QRET, is shown as the lower sequence. The impacts of the combination of the Federal and Queensland RET's are that there is increased load following by the incumbent coal fired power plants. This is expected to adversely affect existing coal plant maintenance schedules, overall plant efficiency and as a result, generation costs. This higher cost of generation may be coupled with reduced earning rates from lower prices.



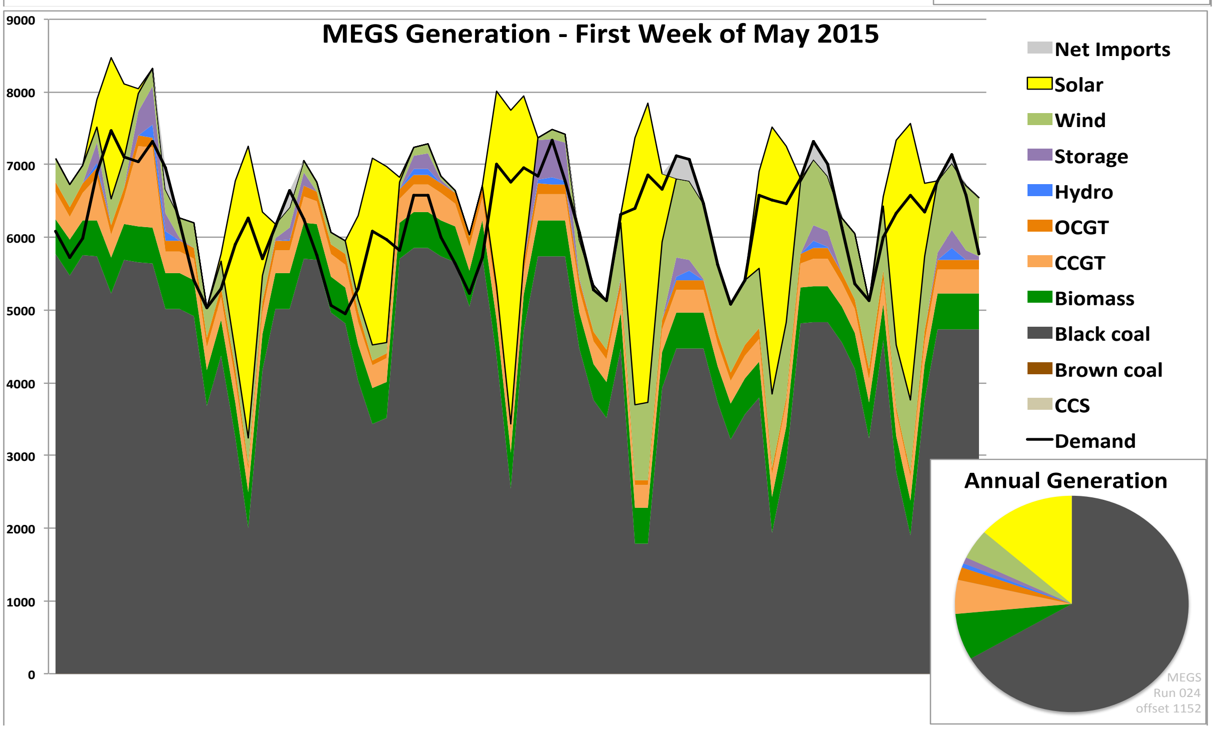
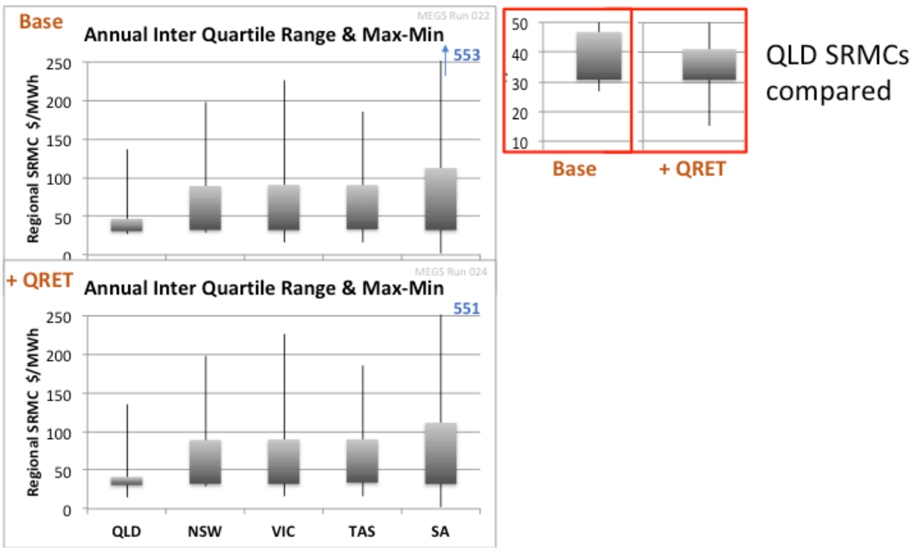


Figure 8: Effect of running regimes in QLD – Base Case (upper) and QRET (lower)

With this ‘modest’ build of new renewable plants in Queensland, no new “start-up shutdown” cycles are likely to impact the coal plant. However, other plant has to work more flexibly. Hydro generation, for example, increases 180 to 290 starts per year and pumped storage from 200 to 360 starts per year. Overall, there is a higher demand in Queensland due to energy losses associated with the increased use of storage facilities.

The impacts on SRMCs are illustrated in Figure 9. In summary, the increased penetration of renewables due to QRET will:

- depress the SRMC in QLD,
- increase market volatility by reducing lowest prices, and
- depending on how incumbent generators fare, may induce economic closures.



Short Run Marginal Cost (SRMC) is the cost of production of the most expensive MWh procured each time period. In normal circumstances it is therefore the **minimum** a buyer can expect to pay for power.

Prices differ from SRMC for many reasons including the need to recover long-run costs, market concentration, subsidy distortions etc. However the **change** in SRMC between scenarios is indicative of the pressure on prices.

Figure 9: Short run marginal cost – QRET

In summary, the impact of QRET is not as large as the headline 50% target might suggest. 17% of the renewable generation is located outside of Queensland and is already accounted for, and 7% is small scale PV already installed. In reality only 25% remains to be added, which is less than the Finkel 2030 scenario. QRET reduces NEM emissions by 5.4Mt, over and above effect of LRET/SRES, with nearly all of those reductions occurring within Queensland.
QRET adds costs to NEM consumer of $610M p.a., over and above the cost of LRET and SRES. In terms of cost of abatement, it achieves emission reductions at $113/t CO_2, which is not dissimilar to the cost of CCS seen in previous work[1]. QRET reduces short run marginal costs in Queensland from $42.2 to $37.0/MWh, putting downward pressure on wholesale prices and the profitability of existing plant operators.

While QRET imposes load following on all Queensland coal fired power generation plants, there are no additional shutdown cycles. However, the economics for coal fired power plants deteriorate. There is more wear and tear through load following and reduced income through downward pressure on prices. Hydro and pump storage do many more starts per year to absorb the variability within the grid.

V-RET

The impact of both LRET and SRES on the operation of the Victorian grid is shown in Figure 10 as the upper sequence. That base case, combined with VRET is shown as the lower sequence. In addition to the running regimes within Victoria, the interconnector flows are shown (for the month of January) which highlight a significant shift in the profile. **If the current brown coal fleet could be made to be more flexible and have a lower minimum load, this would significantly reduce system-running costs. Such an upgrade to increase flexibility and minimum generation would require assessment for both its engineering possibility and its economic viability.**

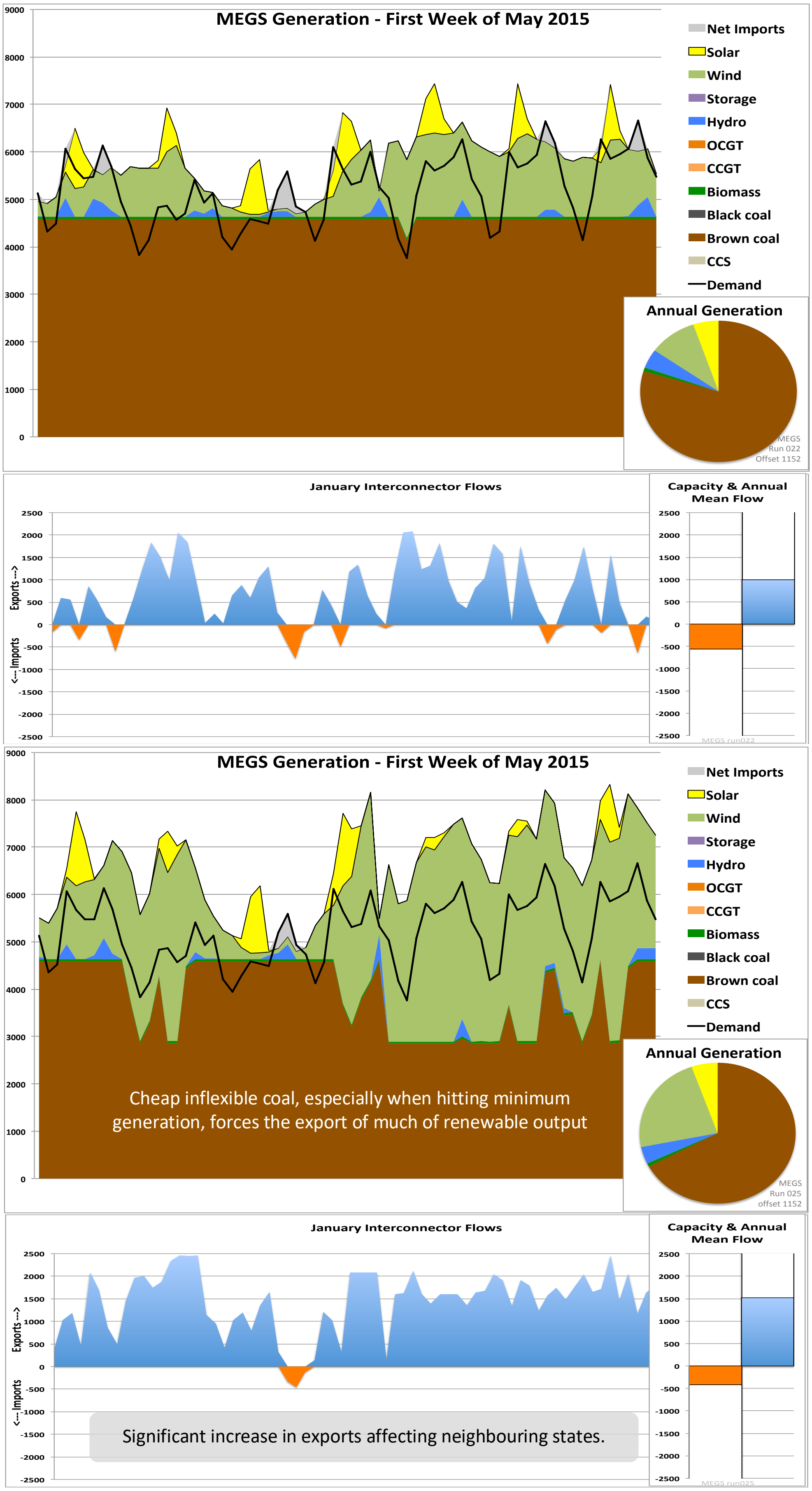


Figure 10: Effect of running regimes in VIC – Base Case (upper) and VRET (lower) with related interconnector flows

Increased penetration of renewables due to VRET will depress the SRMC across much of the NEM (refer to Figure 11). The mean SRMC reduces from $63 to $42/MW, depending on how incumbent generators fare. This may induce economic closures in VIC, NSW or QLD.

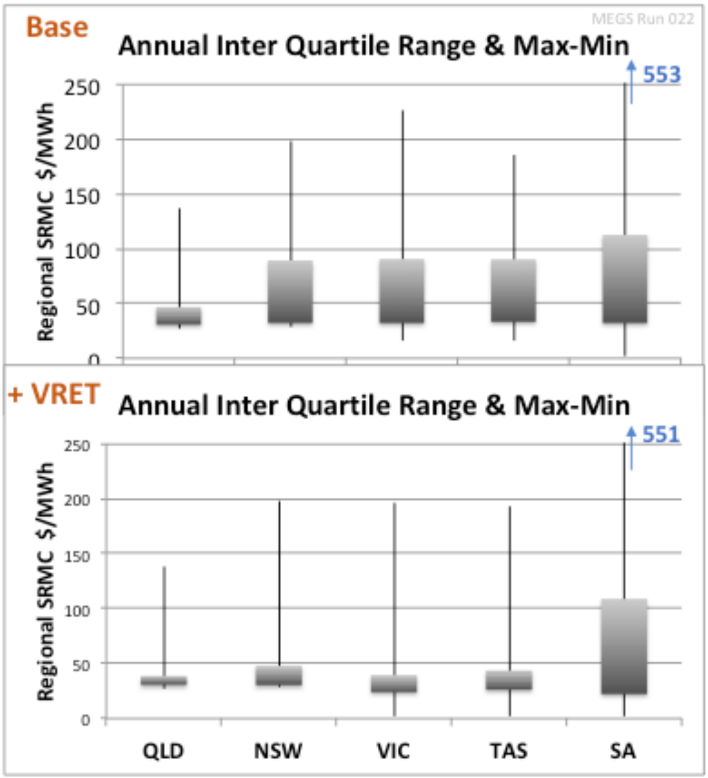


Figure 11: Short run marginal cost – VRET

Short Run Marginal Cost (SRMC) is the cost of production of the most expensive MWh procured each time period. In normal circumstances it is therefore the **minimum** a buyer can expect to pay for power.

Prices differ from SRMC for many reasons including the need to recover long-run costs, market concentration, subsidy distortions etc. However the **change** in SRMC between scenarios is indicative of the pressure on prices.

The impact of VRET is felt more widely across the NEM than QRET, as Victoria has both more interconnectors than Queensland, and the inflexibility of the existing brown coal plant which forces much of extra renewable generation into neighbouring states.

The VRET reduces the NEM emissions by 7.7Mt, over and above effect of LRET, although two thirds of those reductions occur outside of Victoria. VRET also adds costs to NEM consumer of $490M p.a. over and above cost of LRET. In terms of cost of abatement, it achieves emission reductions at $63/t$CO_2$, significantly lower than that achieved by QRET. This is mainly due to it displacing high emission brown coal within the state and better access to rest of the NEM for more cost-effective emissions reduction.

The short run costs in VIC-TAS-NSW reduce from $63 to $43/MWh as a result of VRET, putting significant downward pressure both on wholesale prices in these regions and income of existing plant. This economic pressure is felt by not just Victorian brown coal, but by the New South Wales black coal power plant fleet as "intermittency" is exported. The VRET pushes brown coal out of the market as a baseload supplier 25% of time. Brown coal could be required to run at minimum generation for 10% of the time.

Victoria moves from being balanced (now), to a net exporter of around 4 TWh p.a. with LRET, and to 8 TWh p.a. with VRET.

Effect of RETs on NSW

New South Wales is effectively wedged between Queensland and Victoria in terms of geography and the structure of the NEM grid. While it has no 2030 targets or goals, it has a 2050 state-wide target of net-zero emissions.[7] Black coal power generation plants lose 6% of generation and are required to do more load following with a QRET and VRET, however changes are not dramatic. However, imports increase by about 25% (refer to Figure 12).

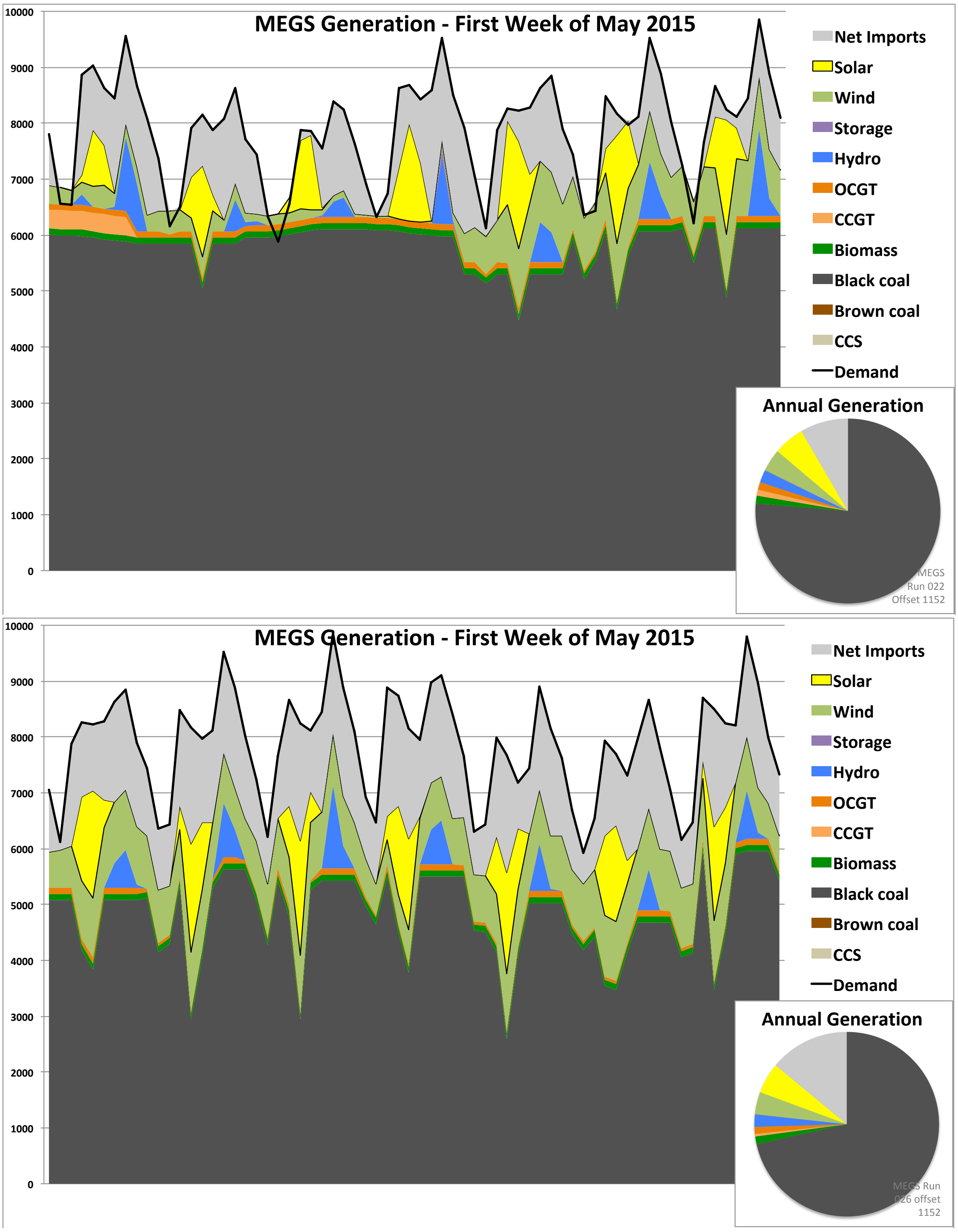


Figure 12: Effect of running regimes in NSW – Base Case (upper) and QRET & VRET combined (lower)

[7] The modelling of the NSW 2050 net zero emissions targets was outside the scope of this work.

VRET and QRET Impact Summary

The pathway to decarbonising the Australian electricity system is complex. No one single technology class will result in the optimum option of low cost, low emissions and high reliability. This extension study examining the State and Federal RETs confirms that to resolve the energy trilemma, a range of technologies will be required.[1]

The base LRET and SRES will raise renewable input to around 24% of the NEM. QRET achieves only a small step beyond the base due to the accounting of its 'fair share' of the LRET which is not built in Queensland. VRET achieves a slightly larger step. The renewable energy consumption is summarised in Table 1.

Table 1: RET Summary – Renewable Energy Consumption

Scenario Modelled	Queensland Note[8]	Renewable Generation in each state as % of energy consumed				
		NSW	VIC	TAS	SA	NEM
2017 (run021)	10% (within QLD) 24% (QRET accounting)	9%	17%	86%	43%	18%
Base (LRET 33 TWh, + SRES) (run022)	18% (within QLD) 35% (QRET accounting)	13%	22%	92%	52%	24%
Base + QRET (run024)	29% (within QLD) 49% (QRET accounting)	12%	22%	92%	52%	28%
Base + VRET (run025)	18% (within QLD) 35% (QRET accounting)	13%	39%	92%	51%	29%
Base + QRET + VRET (run025)	29% (within QLD) 49% (QRET accounting)	13%	39%	92%	51%	32%

Target Achieved	Target Overshot

While this modelling is premised on the successful deployment of Queensland (QRET) and Victorian (VRET) policies, it is important to note the QRET and VRET policies do not deliver emissions reductions from the electricity sector to anywhere near their fair share of our National Paris decarbonisation commitment. Furthermore, significant reductions over and above this initial commitment are still required to meet a 1.5 or 2°C emissions target.

[8] Refer to Figure 7 and associated discussion on QRET.

Progress towards meeting Australia's Nationally Determined Contributions (NDC) commitment at Paris (26-28% reduction on 2005 emissions) has been slow. Both New South Wales and Queensland have had an emissions increase, likely due to the closure of Hazelwood in Victoria, which increased local black coal powered generation in each State. Both South Australia and Tasmania have made significant progress individually, however they are only a small part of overall NEM, and South Australia is heavily reliant on its coal powered neighbour to provide it back up and support services. The carbon emissions results are summarised in Table 2.

Table 2: RET Summary – Effect on Carbon Emissions from the Electricity Sector

Scenario Modelled	**CO_2 Emissions** (MT)					
	QLD	**NSW**	**VIC**	**TAS**	**SA**	**NEM**
2005 *(States estimated)*	*48.4*	*56.7*	*61.1*	*0.5*	*9.2*	176.4
2017 (run021)	48.7 +1%	61.9 +9%	56.9 -7%	0.3	3.2 -65%	171.0 -3%
Base (LRET 33 TWh, + SRES) (run022)	48.3 -	53.4 -6%	56.9 -7%	0.0	2.8 -69%	161.4 -8%
Base + QRET (run024)	43.3 -11%	53.0 -7%	56.9 -7%	0.0	2.8 -69%	156.0 -11%
Base + VRET (run025)	46.4 -4%	50.5 -11%	54.1 -12%	0.0	2.6 -72%	153.7 -13%
Base + QRET + VRET (run025)	41.5 -14%	50.0 -12%	54.1 -12%	0.0	2.6 -72%	148.1 -16%

Emissions Increase	Fair share of Paris or beyond

Figure 13 shows the comparison of the Base + QRET + VRET in 2030 with a 2030 Finkel scenario as described in a previous report.[1] The Base + QRET + VRET sees 10 GW of renewables built within the NEM grid. While this results in no renewables being curtailed, the emissions reductions are only just half way to the fair share of Australia's Paris commitment.

The Finkel 2030 results[1] would result in a much larger renewable build, approximately 30 GW within the NEM, with a significant build in all the NEM States. This would result in a small but still significant curtailment of renewable output. The resulting emission reduction, however, exceeds a 'fair share' commitment to the Paris emissions reduction targets.

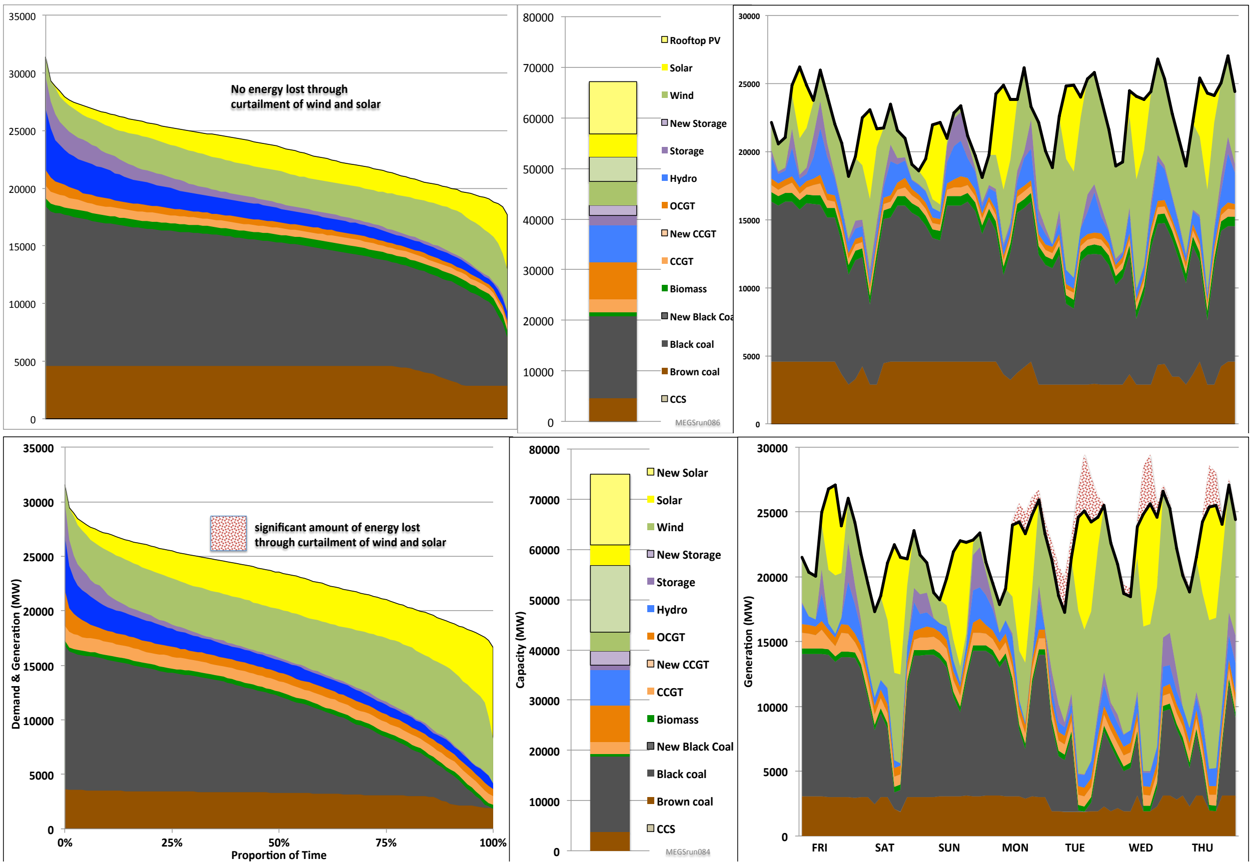


Figure 13: QRET & VRET (upper) compared with "Finkel 2030" (lower)

Figure 14 shows that the various RETs are relatively small steps toward the decarbonisation of the electricity sector. Much more will need to be done across all sectors if Australia is to meet Paris 2030.

To achieve a net zero ambition by 2050 requires deployment of CCS in the early 2030s. For that to occur, all necessary preparatory work and technology demonstration will need to be completed in the 2020s.

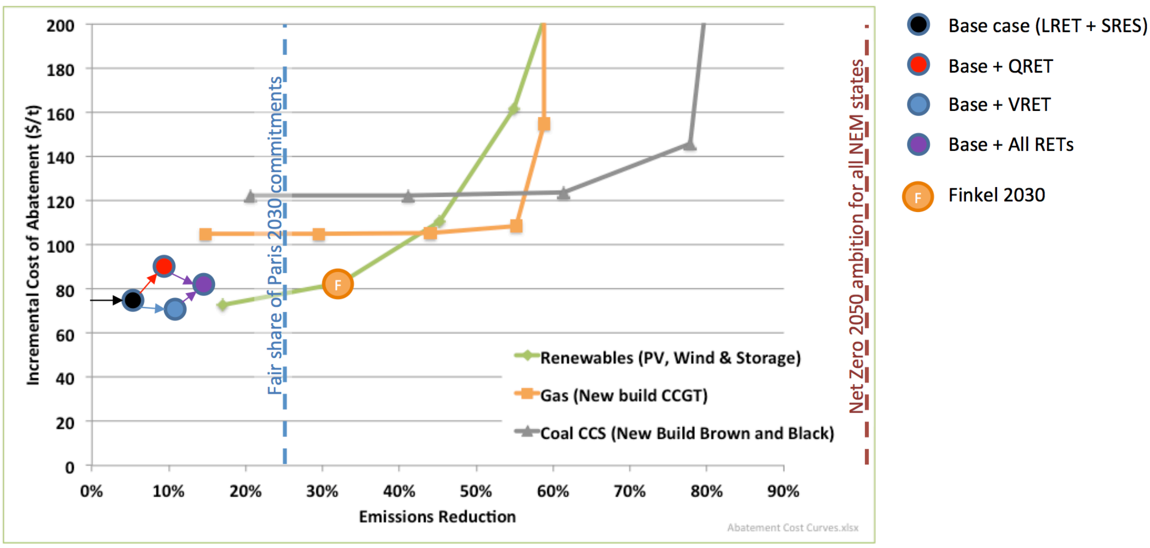


Figure 14: Comparison of alternative pathways and 'least cost pathways' from a 2017 Base Year

Executive Summary

Most Australian states and territories have relied on coal fired power generation for over 80% of their electricity supplies. More recently, Queensland, Victoria, South Australia and ACT have adopted policies to substantively increase sourcing their electricity from renewable energy and targeting net zero emissions aspirations for the future. The state and territory policy positions are broadly consistent, with a minimum renewable energy target specified and aspire to net zero emissions by 2050 at the latest.

How this impacts on the physical operation of the National Energy Market (NEM) has been examined in this work, an extension of the 2017 study, Managing Flexibility Whilst Decarbonising Electricity: the Australian NEM is changing.[1] In particular, the impact of the Queensland and Victorian renewable energy targets (QRET and VRET) has been modelled using MEGS which takes account of the enduring need for grid strength and reliability services.

The broad conclusions of this work are summarised as follows:

QRET & VRET combined achieves neither Finkel 2030 nor electricity's emissions reduction contribution to Paris

- The RETs modelled achieve only half of the required abatement for the electricity sector to meet the Paris Agreement
- Pursuing renewable targets significantly beyond these will decrease effectiveness of solar and wind, as the market saturates and output is curtailed
- Previous modelling has already shown that decarbonisation beyond 40% will need new unabated gas and CCS
- CCS will need to be ready to provide reliable, low emissions, grid supporting electricity in the early 2030's
- Impact of VRET is felt beyond the state boundary
    - Much of new renewable generation is exported to surrounding states, putting downward pressure on wholesale prices
- Impact of QRET does not build as many renewable plants as the headline 50% target might suggest
    - Only half of this target requires new build, effects are mostly absorbed within Queensland

There are significant NEM wide impacts for coal plant

- QRET+VRET do not force any more shutdown cycles than the base case
    - However, there is a significant amount of load following for coal required, pushing up costs, and reducing output
- Investment will be required to facilitate these plants having this capability

[1] Boston, A. Bongers, G, Byrom, S and Staffell, I. (2017). *Managing Flexibility Whilst Decarbonising Electricity – the Australian NEM is changing.* Gamma Energy Technology P/L, Brisbane, Australia.

There is downward pressure on average electricity prices but an upward pressure on volatility

- The RETs increase volatility by suppressing prices during low demand / high renewable output periods
- Any such regulated deterioration of economics of fossil-fuelled plant encourages early closure which will likely raise peak prices

Deep Decarbonisation requires a diverse portfolio of plant

- It is not possible to go beyond 65% decarbonisation with renewables alone without incurring huge uplift costs to the system. In some capex scenarios it makes sense to avoid going beyond even 40% with renewables alone.
- CCS makes a perfect complementary technology for renewables in deep decarbonisation scenarios.
- In addition, there will need to be an element of flexible, low load factor fossil for meeting peaks, providing grid services and supporting the grid in weeks of low renewable production
- Retaining the option for deep decarbonisation requires immediate and continuing investment in the development of CCS, with a strong emphasis on upgrading existing fossil to improve its flexibility to operate in emerging electricity markets

Performance Metrics for Decarbonisation of a Grid

- It is increasingly clear from this study that the "Total System Cost" is the better metric by which to assess the affordability of emissions reduction pathways. Although familiar to many, the Levelised Cost of Electricity (LCOE) would be completely out of the context it was designed for and therefore very misleading when comparing generation options.
- National electricity pricing and energy competitiveness will be a strong function of Total System Cost. The most effective path to a low emissions grid will be to track the "least cost" pathway for transforming the constituent asset portfolio.
- Current Federal and State policy settings drive renewable generation investment. However, in Australia, there are no structural or market mechanisms in place to minimise the Total System Cost and ensure affordability of power. It is recommended that accountability for total system cost is transparently assigned within Australian market and regulatory systems.

Disclaimer

This analysis for report was completed on 30th of June 2017 and therefore the Report does not take into account events or circumstances arising after that time. The authors of the Report take no responsibility to update the Report.

The Reports modelling considers only a limited set of input assumptions which should not be considered entirely exhaustive. Modelling inherently requires assumptions about future behaviours and market interactions, which may result in forecasts that deviate from actual events. There will usually be differences between estimated and actual results, because events and circumstances frequently do not occur as expected, and those differences may be material. The authors of the Report take no responsibility for the modelling presented to be considered as a definitive account.

The authors of the Report highlight that the Report, does not constitute investment advice or a recommendation to you on your future course of action. The authors provide no assurance that the scenarios modelled will be accepted by any relevant authority or third party.

Conclusions in the report are based, in part, on the assumptions stated and on information which is publicly available. No listed author, company or supporter of this report, nor any member or employee thereof undertakes responsibility in any way whatsoever to any person in respect of errors in this Report arising from information that may be later be proven to be incorrect.

In the preparation of this Report the authors have considered and relied upon information sourced from a range of sources believed after due enquiry to be reliable and accurate. The authors have no reason to believe that any information supplied, or obtained from public sources, was false or that any material information has been withheld.

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How to reference this report:

Boston, A., Bongers, G., and Byrom, S. (2018), *The Effect of Renewable Energy Targets on the National Energy Market,* Gamma Energy Technology P/L, Brisbane Australia.

Financial Support:

The authors wish to acknowledge financial assistance provided through Australian National Low Emissions Coal Research and Development (ANLEC R&D). ANLEC R&D is supported by Australian Coal Association Low Emissions Technology Limited and the Australian Government through the Clean Energy Initiative.

About Red Vector:

Red Vector is a UK Limited Company that provides an energy consulting service based on Andy Boston's 30 years experience in the energy industry starting with the nationalised CEGB, through privatisation firstly with PowerGen and thence E.ON, and finally with the Energy Research Partnership.

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About Gamma Energy Technology P/L:

Gamma Energy Technology P/L is an independent energy consulting service, offering a range of technical and support services, including but not limited to power generation technology.

Gamma Energy Technology P/L is proud to contribute to the on-going discussions on energy in Australia as we seek to solve the trilemma of energy supply - to assure energy system security and affordability so that emissions reduction targets are delivered.

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Background

Previous Modelling

The current Australian grid has delivered reliable and secure energy for decades. The majority of electricity in the NEM is provided by coal-fired power generation, a technology that has also delivered the services required for grid stability such as inertia and frequency control. Coal and gas-based technologies have underpinned the energy competitiveness of the Australian economy. However, with increasing penetration of weather dependant, intermittent renewable generation, it is becoming more important to plan for and manage generation asset investment to track close to the least cost and highest reliability path to a low emissions future.

A previous study, sponsored by ANLEC R&D[1], used an innovative modelling approach, MEGS, to examine the Australian NEM. MEGS considered the grid system cost by recognising the importance of firm generation, the cost of balancing the system, and the required flexibility, while on the "pathway" to a lower emissions grid.

Key Points from this study included:

- As well as energy supply, each power generation technology brings with it a different set of grid services such as low emissions, inertia, frequency control, flexibility etc
- The NEM is unique when compared other international grid systems; it consists of 5 State-based grids that are only weakly interconnected
- The characteristics of the NEM plays a significant role in determining the value of an additional asset placed on the system. Each State grid will have unique asset requirements and a material impact on the overall NEM system
- It shows that decisions based on technologies with the lowest LCOE can result in a high cost grid system at deep decarbonisation levels due to misleading nature of this metric

The results highlight that approaches to meet short-term emissions targets (e.g: Paris 2030) can be suboptimal if they ignore the long term. The lowest cost energy supply technologies change as NEM decarbonisation proceeds. For example, at high penetration, renewables become increasingly expensive to the grid.

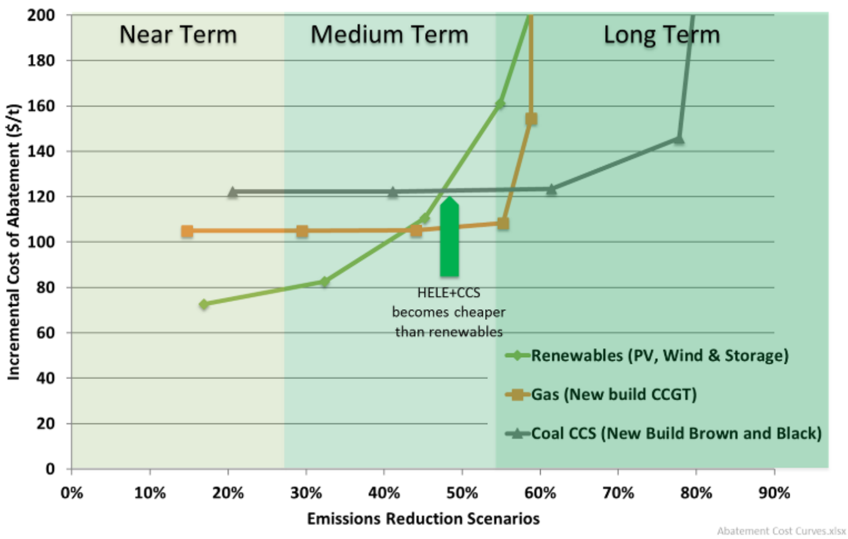


Figure 1: Cost of abatement with increasing emissions reductions from 2017

In Figure 1, renewables costs increase due to intermittency and curtailment. Inflexions for other technologies occur when their emissions limits are reached. At high decarbonisation levels, dispatchable power like coal or gas with carbon capture and storage (CCS) will be required to deliver the required resilience for grid stability**. It can also deliver the deepest decarbonisation ambitions at the lowest cost.**

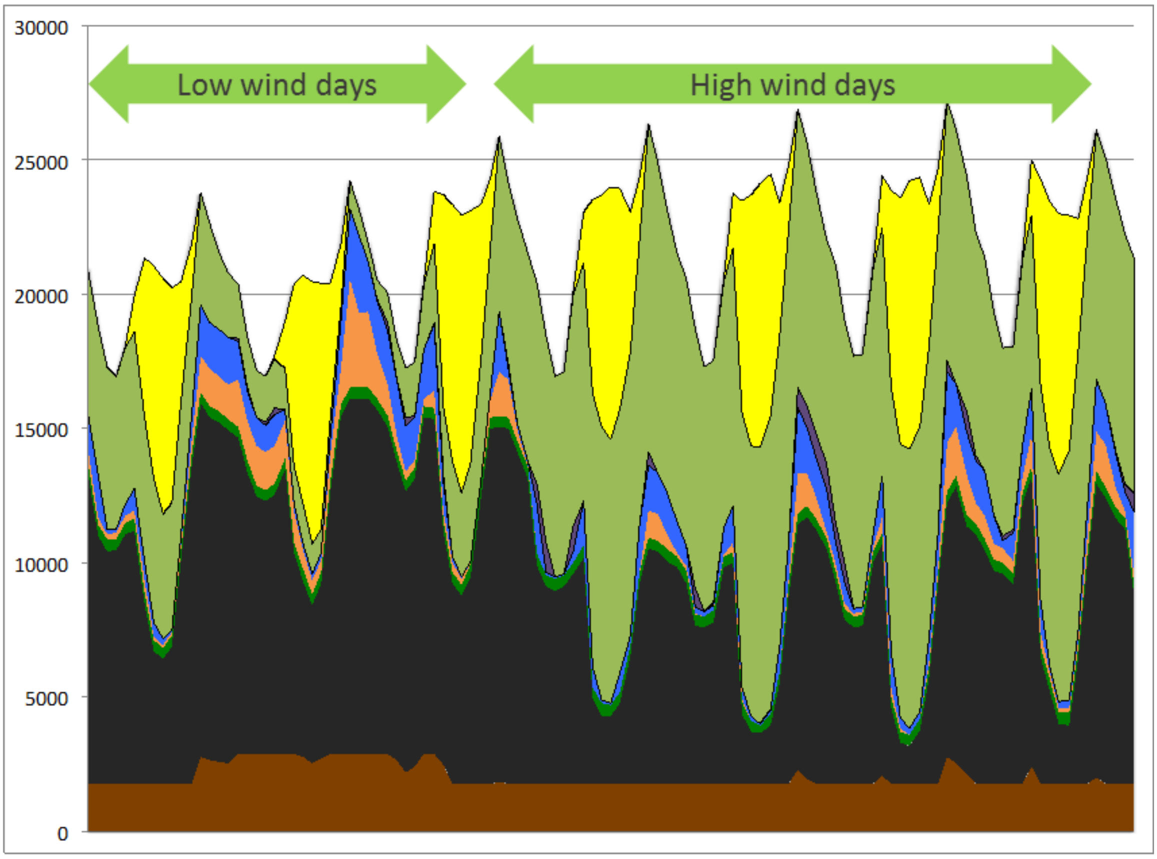


Figure 2: Modelled 7-day generation (high renewables scenario)

High penetrations of wind and solar PV will require companion low carbon technologies if they are to provide firm capacity that is available "on-demand" (refer to Figure 2). In high renewables scenarios, the existing fossil-fuelled power plant (especially black coal) will have to become increasingly flexible on a daily basis.

This is a new operating paradigm for coal assets on the NEM. It requires either new build or investment to upgrade existing plant to ensure they have such flexibility.

Key Terminology / Concepts

The following terms and concepts are defined here for a common understanding of their use within this report

- **Cycling**:
  Range of operations in which a plant's output changes, including starting up and shutting down, ramping up and down, and operating at part-load (less than full output).[2]
- **Forced Outage**:
  An unplanned component failure or other condition that requires the unit be removed from service immediately, within six hours, or before the end of the next weekend.[2]
- **Ramping**:
  Output that varies between full and minimum levels in order to follow changes in demand.[2]
- **Start**:
  Starting of a unit that is offline. Starts are described as hot, warm, or cold, depending on the temperatures of the metal in the turbine.[2]
- **Two Shifting**:
  Operational sequence whereby a generating unit is started and shutdown within a 24-hour period. Typically, the shutdown is overnight. Also used as a general term describing more than one shutdown within a 24-hour period.[2]
- **Wear and Tear**:
  Wear means the component reaches the end of its natural life through ordinary causes, though wear can be accelerated by cycling. Tear refers to an abnormal event that accelerates the life, such as occurs during poor control of operating conditions. While tear may occur during baseload operations, they are more likely during some cycling modes.[2]
- **Frequency control ancillary services (FCAS):**
  Frequency control is critical to power system security, and in the NEM, AEMO is responsible for procuring sufficient frequency control ancillary services (FCAS) to maintain frequency within prescribed operating standards. This task currently relies heavily on the services provided by synchronous generation, although newer technologies (especially storage) are in theory able to provide these services. However, this comes at significant cost if renewable output is curtailed to provide headroom for reserve.[3]
- **Inertia:**
  Inertia is provided by the large rotating masses of all thermal and some hydro generators and turbines. These synchronous machines rotate with the system frequency and their mass resists changes to frequency instantaneously. Inertia could therefore be seen as a store of kinetic energy within the grid itself which is drawn on during a system disturbance. In the past inertia has been abundant in the NEM and it is not directly valued at present, so scarcity is not transparent. However, as conventional plant continues to be displaced by low inertia technologies (intermittent), there are signs of inertia becoming scarce in some parts of the network. Low inertia systems require more FCAS services to be procured and these need to respond on a shorter timescale.[3]

[2] Cochran, J., Lew, D., Nikhil Kumar, N. (2013). *Flexible Coal Evolution from Baseload to Peaking Plant.* National Renewable Energy Laboratory, Colorado, USA. NREL/BR-6A20-60575.
[3] Finkel, A., et al. (2017) *Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future*, Commonwealth of Australia.

The life of a steam turbine and other temperature sensitive components is related to thermal transients experienced over time. Most temperature components have well defined thermal limits and constraints. For a ‘sample’ steam turbine, Figure 3[4] requires slow temperature changes to manage the thermal stress in their heavy metal components.

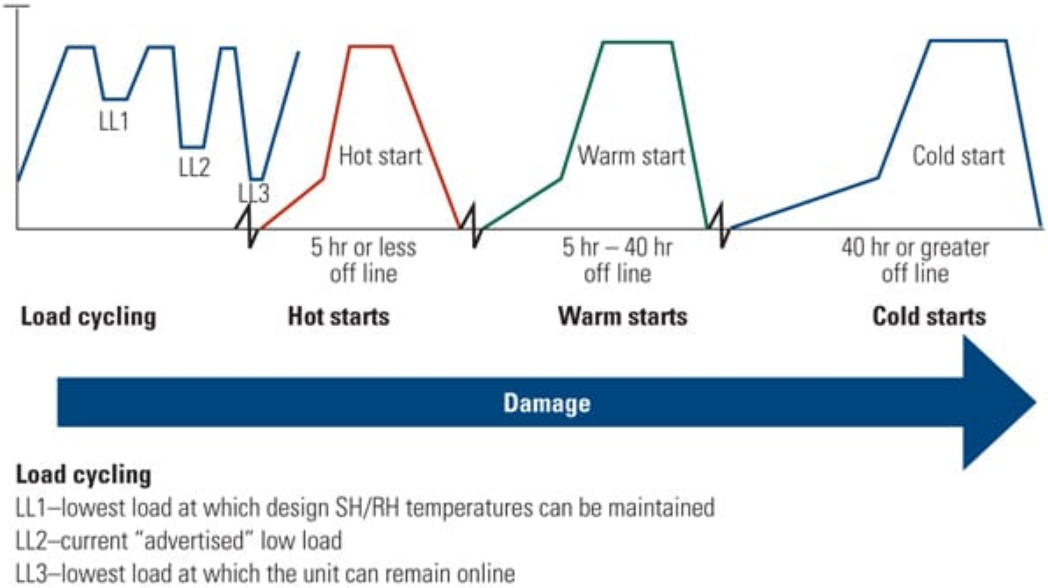


Figure 3: Relative damage caused by cycling steam plants

[4] Lefton, S.A. and Hilleman, D. (2011) *Make Your Plant Ready for Cycling Operations*, available at http://www.powermag.com/make-your-plant-ready-for-cycling-operations

MEGS: Overview and Capabilities

The model at the heart of this work is **MEGS** – **M**odelling **E**nergy and **G**rid **S**ervices. Like many models, it balances energy for each calculated point in time for a grid of interconnected regions, but what makes it unique is its attention to the engineering constraints and ancillary services that ensure a grid is operable. In MEGS, these boil down to ensuring:

- Sufficient fast acting reserve is available to each region,
- A minimum level of inertia is connected in each region, and
- The grid is reliable and operable.

Figure 4 shows how MEGS compares to other modelling techniques.

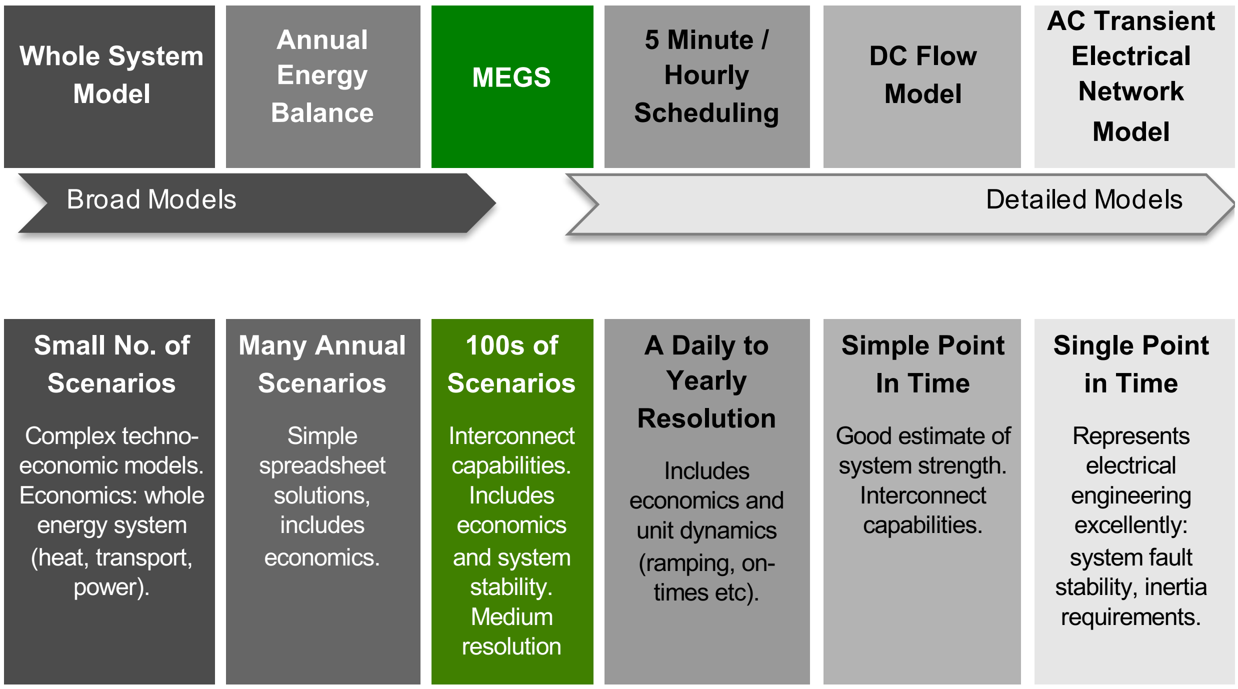


Figure 4: MEGS model in comparison to other methodologies

While MEGS is typically configured to model power plants as aggregated tranches of similar units, it may be configured as an individual plant configuration. For each modelled point in time (typically 2-3 hours apart), the solver determines generation and reserve provision from plant whilst minimising system short run costs which are given by fuel, carbon and non-fuel variable costs.

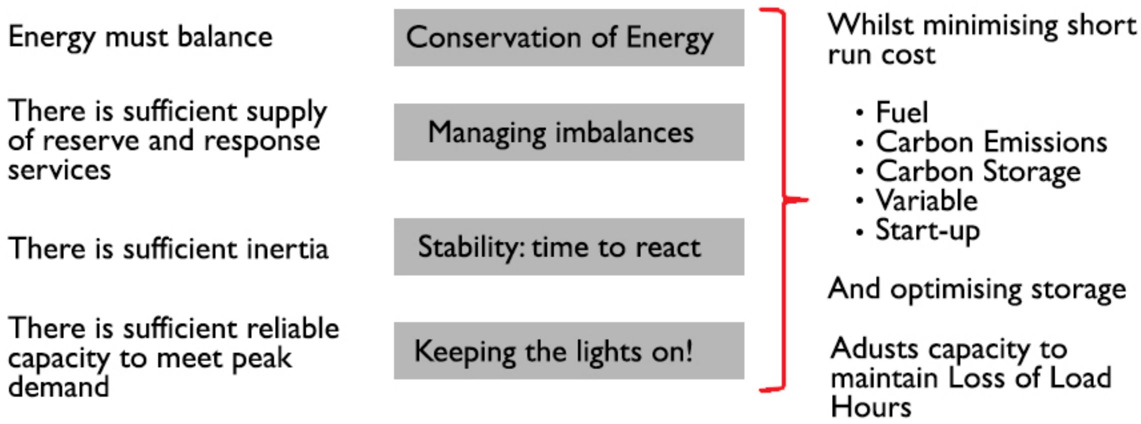


Figure 5: MEGS balances several services essential to grid operation

Forecasting into long term futures is inherently speculative. The ability to explore large uncertainties in future scenarios is an additional MEGS capability. When configured in this format, the model is denoted as **S-MEGS**. S-MEGS can model up to five key uncertainties via a Monte Carlo analysis:

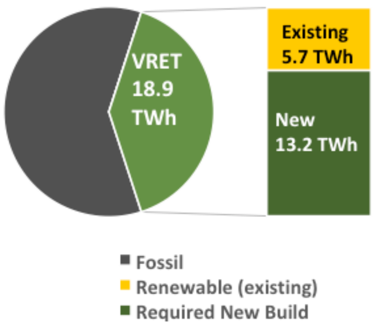
- Weather: chosen from historic data affecting renewables and demand,
- Fuel Prices: chosen annually from a lognormal distribution,
- Capex: chosen annually from a lognormal distribution,
- New Build Projects: large projects are all or nothing, chosen randomly, and
- Clean Tech Build: capacity of renewables or CCS constructed is chosen from a uniform distribution.

For each simulation, a value is chosen for the uncertain parameters from a given distribution. This sets a portfolio of plant with a defined set of costs and historic weather data. A typical S-MEGS run results in 100’s of simulations with high-level outputs reported for each one. Viewing a distribution of probabilistic endpoints can be instructive to both recognize patterns that may emerge and highlight the boundaries of an outcome envelope. Although S-MEGS offers a wide range of input parameters which can vary, it is best to limit input variation to the minimum needed to explore the issue in question.

VRET Background

In 2016, the Victorian Government committed to renewable energy generation targets (VRET) of 25% by 2020, 40% by 2025, and a net zero emissions target by 2050. These targets have recently been legislated.[5] To achieve the VRET, a reverse auction scheme will be employed, designed to deliver up to 1,500MW by 2020 and 5,400MW by 2025 of new, large-scale renewable energy projects.

Figure 6 details VRET in terms of renewable generation, both existing and new build generation.

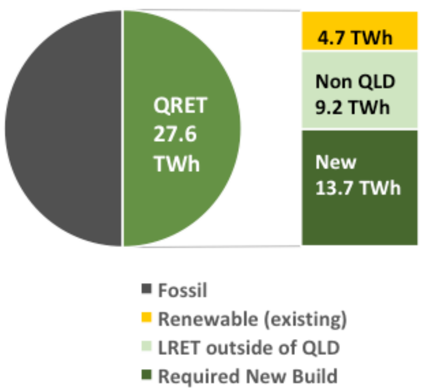


At 420 MW, Macarthur is Australia's largest wind farm. VRET's required new build is equivalent to 10 Macarthur's.

Figure 6: VRET definition - 40% renewable target by generation

QRET Background

In 2016, the Queensland Government commenced an investigation into achieving a 50% renewable energy target in Queensland by 2030. An Expert Panel's report, "Credible pathways to a 50% renewable energy target for Queensland" was delivered in 2017.[5] The report found that Queensland has a high potential to grow its renewable energy industry as a result of decreasing technology costs, market dynamics and a strong pipeline of proposed large-scale renewable projects. The Queensland Government accepted almost all of the recommendations from the Expert Panel.[6] Figure 7 details QRET in terms of renewable generation sources, existing, non-Queensland LRET renewable generation and generation required from new build.



At 102 MW Nyngan is the largest PV farm proposed for Australia. QRET's required new build is equivalent to 60 Nyngan's.

Figure 7: QRET definition - 50% renewable target by generation

[5] Stock, P., Alexander, D., Andrew Stock, A. and Bourne, G. (2017) *Renewables Ready: States Leading the Charge.* Climate Change Council, Victoria, Australia, ISBN: 978-1-925573-28-2.

[6] Department of Energy and Water Supply (2017). *Queensland Government response to the Renewable Energy Expert Panel inquiry into credible pathways to a 50 per cent renewable energy target in Queensland by 2030.* Queensland Government, Australia.

Modelling Q-RET and V-RET

The NEM grid is a composite of 5 State based grids that are weakly interconnected. Many of these States have privatised their electricity businesses and continue to develop their respective environmental performance measures separately. The scenarios modelled in the prior work[1] did not consider the impact of individual State targets and goals, but rather looked at one target for the NEM as a whole.

The aim of this phase of modelling is to examine the effect of fulfilling the various State and Federal Renewable Energy Targets (RETs) examining:

- The decarbonisation of the NEM as a whole,
- The likely evolution of prices across the NEM,
- The effect on NSW (which has no RET of its own),
- The effect on the running regimes of plant directly affected by the RETs, and
- The impact of additional storage as a load and generator.

Five scenarios were modelled, one reference case based on 2017 and four combinations of RETs in 2030. This timescale allows the RETs to reach their targets and a comparison with the Finkel study[3] which also focused on this year. The five scenarios were:

1. **Reference**
   2017 reference year.
2. **SRES + LRET (Base)**
   This scenario includes the Federal support for the 33 GWh Large-scale Renewable Energy Target (LRET) across the NEM by 2020. In addition, it is assumed that the Small-scale Renewable Energy Scheme (SRES) continues to support rooftop PV at current installation rate of 750 MW p.a. until 2020, and then at half that rate until 2030 when scheme ends.
3. **Base + QRET**
   This scenario builds on SRES and LRET by adding Queensland's Renewable Energy Target (QRET) where 50% of Queensland's demand met by renewables by 2030.
4. **Base + VRET**
   This scenario builds on SRES and LRET by adding Victoria's Renewable Energy Target (VRET) of 40% of Victoria's demand met by renewables by 2025.
5. **Base + QRET + VRET**
   This scenario combines all the schemes from 2-4 above.

It is important to note that the RETs are not entirely independent. For example, Queensland's Department of Energy and Water Supply (DEWS) has explicitly stated[6] that QRET "includes Queensland's pro-rata share of renewable energy generation under the LRET." Given that little LRET supported plant has been built in Queensland, this means that a considerable proportion (about 28%) of LRET plant in the other 4 States is considered by Queensland to count towards its own target. As QRET is not completely additive to the Queensland grid, it allows for double accounting of renewable output (refer to Figure 7 for more detail on QRET). In fact, renewable energy output in Victoria may also count towards VRET meaning some of this could end up being triple accounted.

Q-RET

The impact of both LRET and SRES (the Commonwealth RETs) on the operation of the Queensland grid is shown Figure 8 as the upper sequence for a sample week based on the weather of May 2015. That base case, combined with QRET, is shown as the lower sequence. The impacts of the combination of the Federal and Queensland RET's are that there is increased load following by the incumbent coal fired power plants. This is expected to adversely affect existing coal plant maintenance schedules, overall plant efficiency and as a result, generation costs. This higher cost of generation may be coupled with reduced earning rates from lower prices.

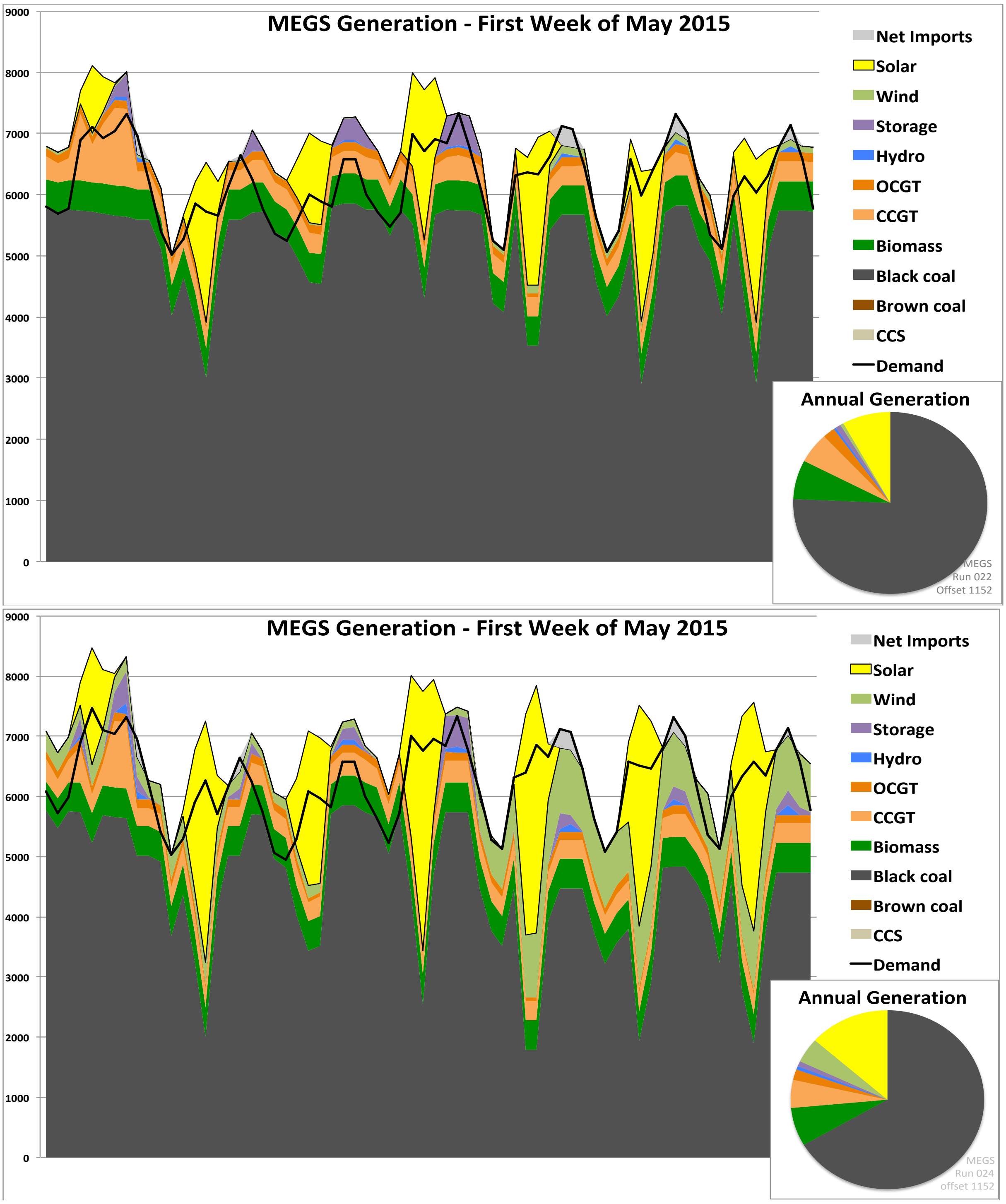
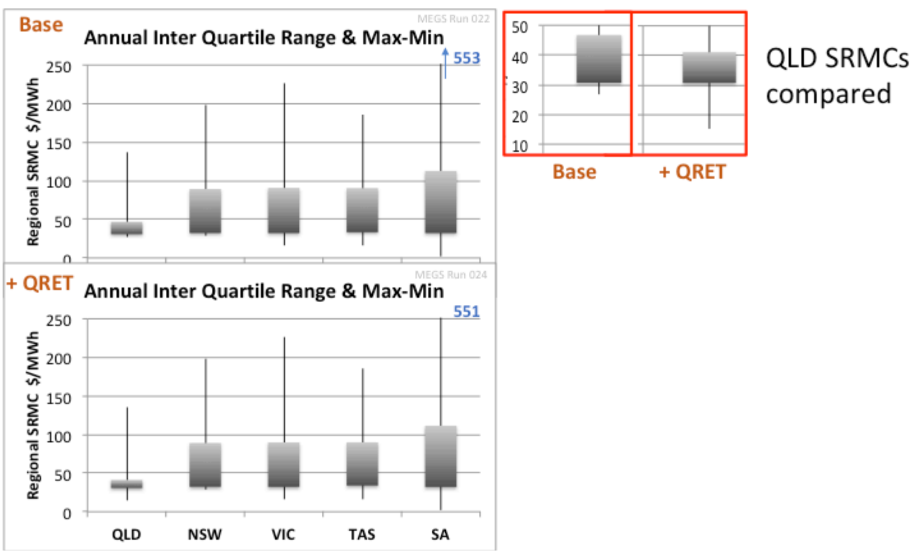


Figure 8: Effect of running regimes in QLD – Base Case (upper) and QRET (lower)

With this 'modest' build of new renewable plants in Queensland, no new "start-up shutdown" cycles are likely to impact the coal plant. However, other plant has to work more flexibly. Hydro generation, for example, increases 180 to 290 starts per year and pumped storage from 200 to 360 starts per year. Overall, there is a higher demand in Queensland due to energy losses associated with the increased use of storage facilities.

The impacts on SRMCs are illustrated in Figure 9. In summary, the increased penetration of renewables due to QRET will:

- depress the SRMC in QLD,
- increase market volatility by reducing lowest prices, and
- depending on how incumbent generators fare, may induce economic closures.



Short Run Marginal Cost (SRMC) is the cost of production of the most expensive MWh procured each time period. In normal circumstances it is therefore the **minimum** a buyer can expect to pay for power.

Prices differ from SRMC for many reasons including the need to recover long-run costs, market concentration, subsidy distortions etc. However the **change** in SRMC between scenarios is indicative of the pressure on prices.

Figure 9: Short run marginal cost – QRET

In summary, the impact of QRET is not as large as the headline 50% target might suggest. 17% of the renewable generation is located outside of Queensland and is already accounted for, and 7% is small scale PV already installed. In reality only 25% remains to be added, which is less than the Finkel 2030 scenario. QRET reduces NEM emissions by 5.4Mt, over and above effect of LRET/SRES, with nearly all of those reductions occurring within Queensland.
QRET adds costs to NEM consumer of $610M p.a., over and above the cost of LRET and SRES. In terms of cost of abatement, it achieves emission reductions at $113/t CO_2, which is not dissimilar to the cost of CCS seen in previous work[1]. QRET reduces short run marginal costs in Queensland from $42.2 to $37.0/MWh, putting downward pressure on wholesale prices and the profitability of existing plant operators.

While QRET imposes load following on all Queensland coal fired power generation plants, there are no additional shutdown cycles. However, the economics for coal fired power plants deteriorate. There is more wear and tear through load following and reduced income through downward pressure on prices. Hydro and pump storage do many more starts per year to absorb the variability within the grid.

V-RET

The impact of both LRET and SRES on the operation of the Victorian grid is shown in Figure 10 as the upper sequence. That base case, combined with VRET is shown as the lower sequence. In addition to the running regimes within Victoria, the interconnector flows are shown (for the month of January) which highlight a significant shift in the profile. **If the current brown coal fleet could be made to be more flexible and have a lower minimum load, this would significantly reduce system-running costs. Such an upgrade to increase flexibility and minimum generation would require assessment for both its engineering possibility and its economic viability.**

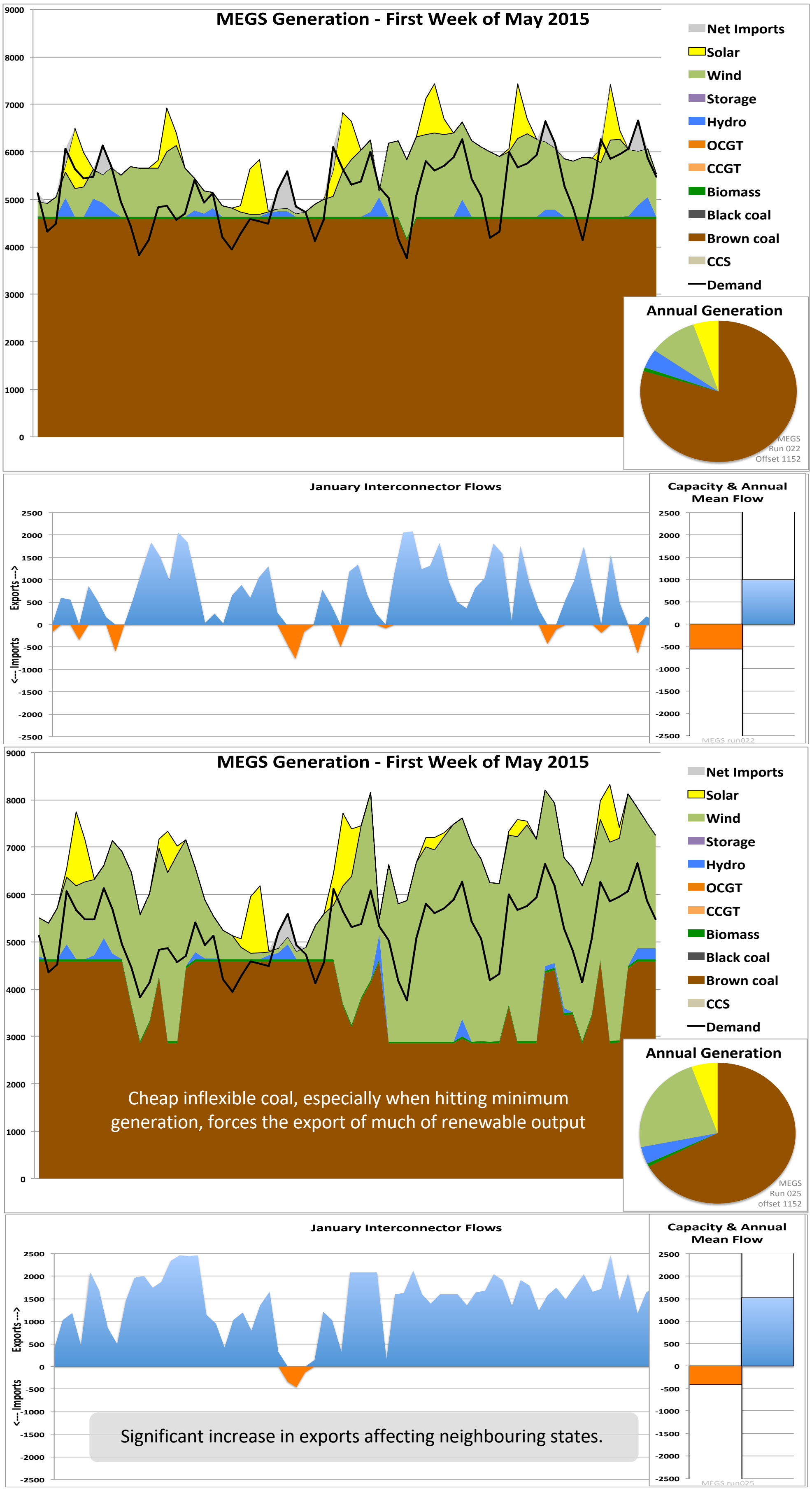
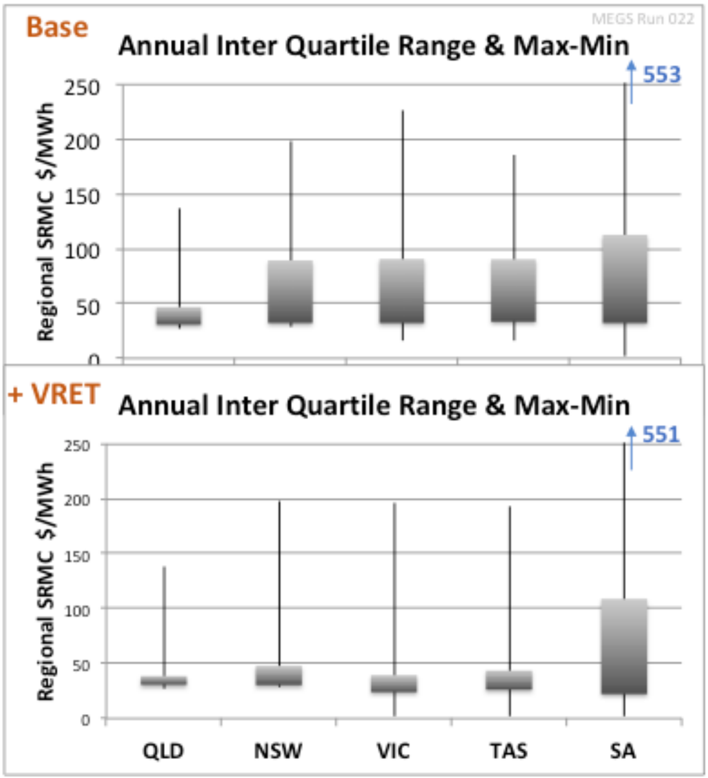


Figure 10: Effect of running regimes in VIC – Base Case (upper) and VRET (lower) with related interconnector flows

Increased penetration of renewables due to VRET will depress the SRMC across much of the NEM (refer to Figure 11). The mean SRMC reduces from $63 to $42/MW, depending on how incumbent generators fare. This may induce economic closures in VIC, NSW or QLD.



Short Run Marginal Cost (SRMC) is the cost of production of the most expensive MWh procured each time period. In normal circumstances it is therefore the **minimum** a buyer can expect to pay for power.

Prices differ from SRMC for many reasons including the need to recover long-run costs, market concentration, subsidy distortions etc. However the **change** in SRMC between scenarios is indicative of the pressure on prices.

Figure 11: Short run marginal cost – VRET

The impact of VRET is felt more widely across the NEM than QRET, as Victoria has both more interconnectors than Queensland, and the inflexibility of the existing brown coal plant which forces much of extra renewable generation into neighbouring states.

The VRET reduces the NEM emissions by 7.7Mt, over and above effect of LRET, although two thirds of those reductions occur outside of Victoria. VRET also adds costs to NEM consumer of $490M p.a. over and above cost of LRET. In terms of cost of abatement, it achieves emission reductions at $63/t$CO_2$, significantly lower than that achieved by QRET. This is mainly due to it displacing high emission brown coal within the state and better access to rest of the NEM for more cost-effective emissions reduction.

The short run costs in VIC-TAS-NSW reduce from $63 to $43/MWh as a result of VRET, putting significant downward pressure both on wholesale prices in these regions and income of existing plant. This economic pressure is felt by not just Victorian brown coal, but by the New South Wales black coal power plant fleet as "intermittency" is exported. The VRET pushes brown coal out of the market as a baseload supplier 25% of time. Brown coal could be required to run at minimum generation for 10% of the time.

Victoria moves from being balanced (now), to a net exporter of around 4 TWh p.a. with LRET, and to 8 TWh p.a. with VRET.

Effect of RETs on NSW

New South Wales is effectively wedged between Queensland and Victoria in terms of geography and the structure of the NEM grid. While it has no 2030 targets or goals, it has a 2050 state-wide target of net-zero emissions.[7] Black coal power generation plants lose 6% of generation and are required to do more load following with a QRET and VRET, however changes are not dramatic. However, imports increase by about 25% (refer to Figure 12).

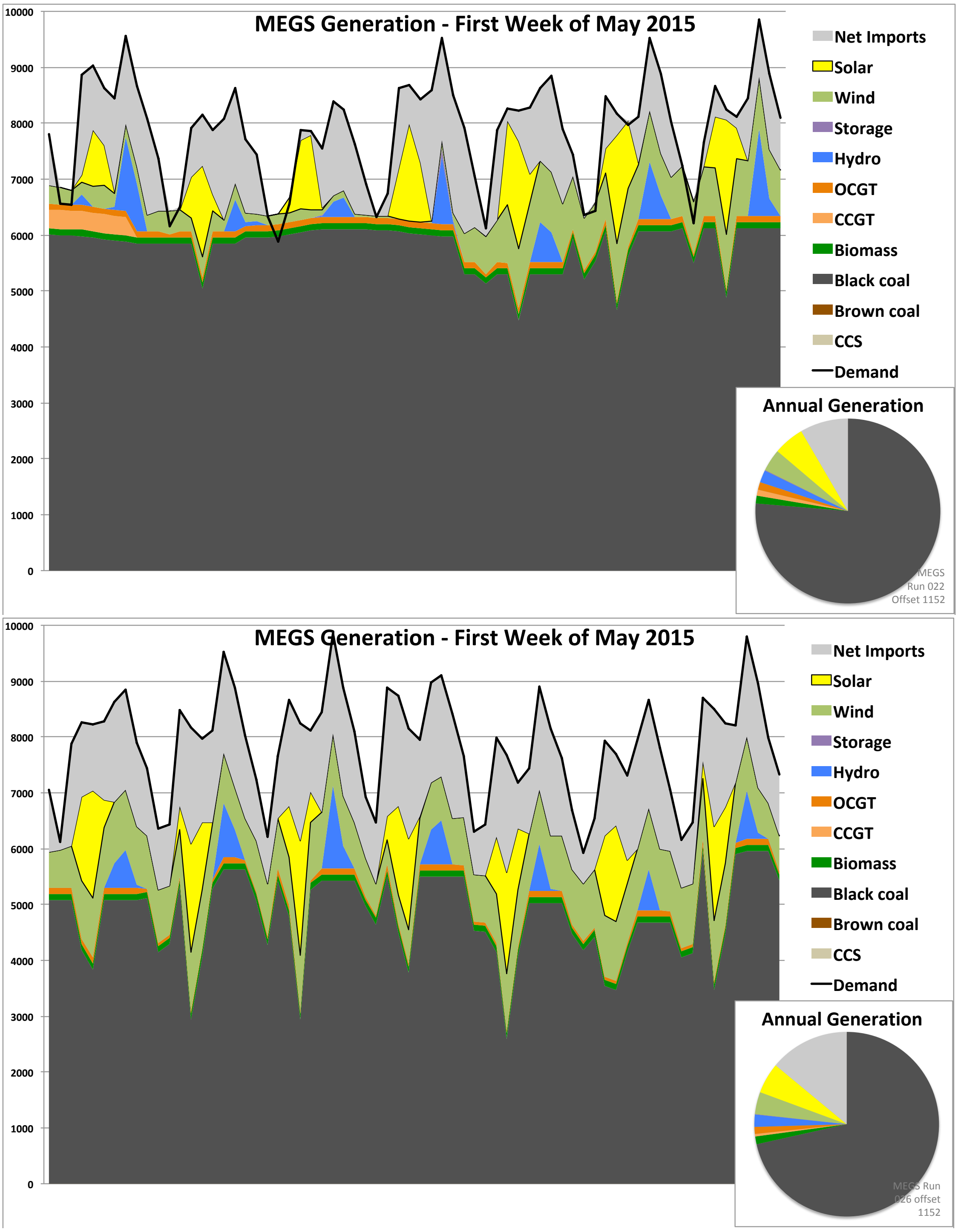


Figure 12: Effect of running regimes in NSW – Base Case (upper) and QRET & VRET combined (lower)

[7] The modelling of the NSW 2050 net zero emissions targets was outside the scope of this work.

VRET and QRET Impact Summary

The pathway to decarbonising the Australian electricity system is complex. No one single technology class will result in the optimum option of low cost, low emissions and high reliability. This extension study examining the State and Federal RETs confirms that to resolve the energy trilemma, a range of technologies will be required.[1]

The base LRET and SRES will raise renewable input to around 24% of the NEM. QRET achieves only a small step beyond the base due to the accounting of its 'fair share' of the LRET which is not built in Queensland. VRET achieves a slightly larger step. The renewable energy consumption is summarised in Table 1.

Table 1: RET Summary – Renewable Energy Consumption

Scenario Modelled	Queensland Note[8]	Renewable Generation in each state as % of energy consumed				
		NSW	VIC	TAS	SA	NEM
2017 (run021)	10% (within QLD) 24% (QRET accounting)	9%	17%	86%	43%	18%
Base (LRET 33 TWh, + SRES) (run022)	18% (within QLD) 35% (QRET accounting)	13%	22%	92%	52%	24%
Base + QRET (run024)	29% (within QLD) 49% (QRET accounting)	12%	22%	92%	52%	28%
Base + VRET (run025)	18% (within QLD) 35% (QRET accounting)	13%	39%	92%	51%	29%
Base + QRET + VRET (run025)	29% (within QLD) 49% (QRET accounting)	13%	39%	92%	51%	32%

Target Achieved	Target Overshot

While this modelling is premised on the successful deployment of Queensland (QRET) and Victorian (VRET) policies, it is important to note the QRET and VRET policies do not deliver emissions reductions from the electricity sector to anywhere near their fair share of our National Paris decarbonisation commitment. Furthermore, significant reductions over and above this initial commitment are still required to meet a 1.5 or 2°C emissions target.

[8] Refer to Figure 7 and associated discussion on QRET.

Progress towards meeting Australia's Nationally Determined Contributions (NDC) commitment at Paris (26-28% reduction on 2005 emissions) has been slow. Both New South Wales and Queensland have had an emissions increase, likely due to the closure of Hazelwood in Victoria, which increased local black coal powered generation in each State. Both South Australia and Tasmania have made significant progress individually, however they are only a small part of overall NEM, and South Australia is heavily reliant on its coal powered neighbour to provide it back up and support services. The carbon emissions results are summarised in Table 2.

Table 2: RET Summary – Effect on Carbon Emissions from the Electricity Sector

Scenario Modelled	**CO_2 Emissions** (MT)					
	QLD	**NSW**	**VIC**	**TAS**	**SA**	**NEM**
2005 *(States estimated)*	*48.4*	*56.7*	*61.1*	*0.5*	*9.2*	176.4
2017 (run021)	48.7 +1%	61.9 +9%	56.9 -7%	0.3	3.2 -65%	171.0 -3%
Base (LRET 33 TWh, + SRES) (run022)	48.3 -	53.4 -6%	56.9 -7%	0.0	2.8 -69%	161.4 -8%
Base + QRET (run024)	43.3 -11%	53.0 -7%	56.9 -7%	0.0	2.8 -69%	156.0 -11%
Base + VRET (run025)	46.4 -4%	50.5 -11%	54.1 -12%	0.0	2.6 -72%	153.7 -13%
Base + QRET + VRET (run025)	41.5 -14%	50.0 -12%	54.1 -12%	0.0	2.6 -72%	148.1 -16%

Emissions Increase	Fair share of Paris or beyond

Figure 13 shows the comparison of the Base + QRET + VRET in 2030 with a 2030 Finkel scenario as described in a previous report.[1] The Base + QRET + VRET sees 10 GW of renewables built within the NEM grid. While this results in no renewables being curtailed, the emissions reductions are only just half way to the fair share of Australia's Paris commitment.

The Finkel 2030 results[1] would result in a much larger renewable build, approximately 30 GW within the NEM, with a significant build in all the NEM States. This would result in a small but still significant curtailment of renewable output. The resulting emission reduction, however, exceeds a 'fair share' commitment to the Paris emissions reduction targets.

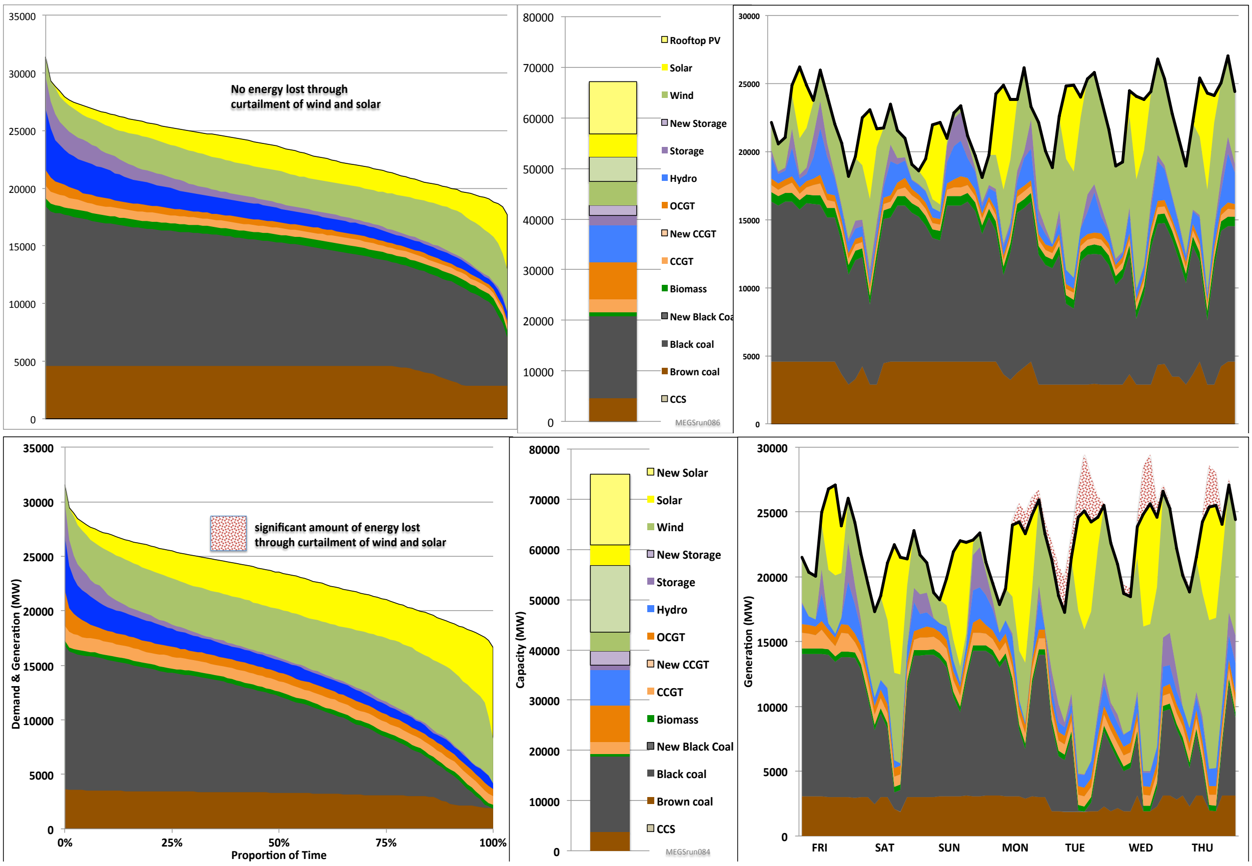


Figure 13: QRET & VRET (upper) compared with “Finkel 2030” (lower)

Figure 14 shows that the various RETs are relatively small steps toward the decarbonisation of the electricity sector. Much more will need to be done across all sectors if Australia is to meet Paris 2030.

To achieve a net zero ambition by 2050 requires deployment of CCS in the early 2030s. For that to occur, all necessary preparatory work and technology demonstration will need to be completed in the 2020s.

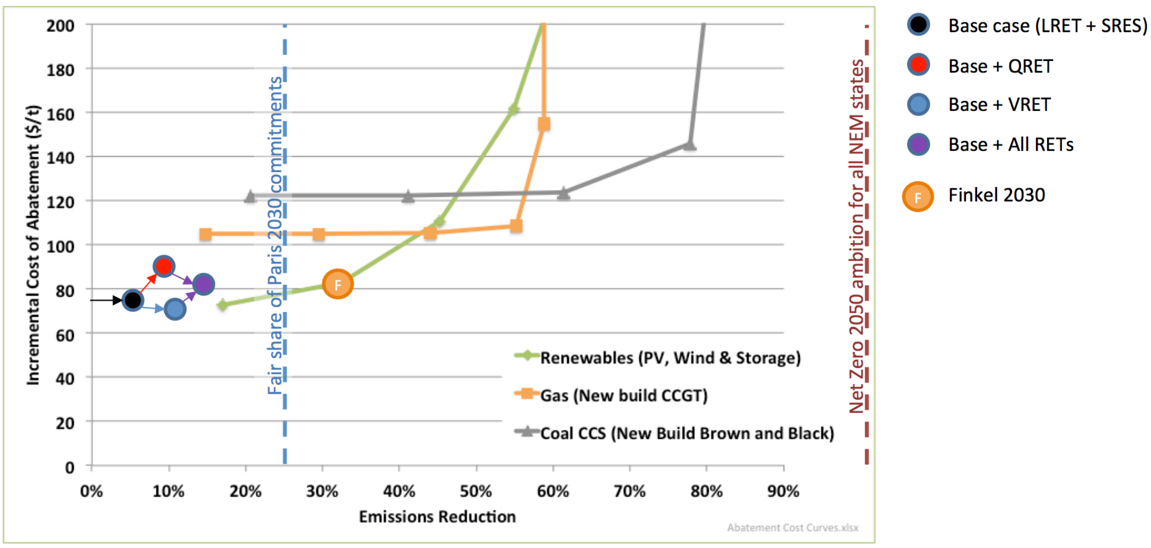


Figure 14: Comparison of alternative pathways and ‘least cost pathways’ from a 2017 Base Year

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