The Trilemma Scale -
A Decision Support Tool for the Energy Trilemma: How does CCS fare?

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Abstract

The World Energy Council (WEC) definition of energy sustainability is based on three dimensions [1], energy security, energy equity and environmental sustainability. The process of adequately addressing these three dimensions is commonly referred to as the Energy Trilemma.

Most power generation networks were designed prior to development of the current range of technologies, when choices were limited to fossil fuels and hydro. Improvements in reliability and efficiency have been made over time, but environmental considerations are relatively recent.

It is widely acknowledged that a range of low-emissions technologies will be required to meet the targets of the Paris COP21 agreement and that no single technology or class of technologies can efficiently and effectively supply all our energy needs [2,3].

One of the issues policy makers must consider as they aim to achieve energy sustainability is the selection of power generation technologies to include in networks.

Several indices are available to assist decision-makers to address the energy trilemma, but all have limitations for comparison of individual technologies.

Examining these issues, it became apparent that a systematic, transparent, quantitative method to characterise individual technologies across all three dimensions of the Energy Trilemma would be useful.

Consequently, a new and simple decision support tool, the Trilemma Scale, was developed to quantitatively inform the community and policy makers. The Trilemma Scale enables comparison of the contribution of each power generation technology to the Energy Trilemma based on cost, reliability and emissions and transforms the comparative analytical data of each technology into a single metric – the Trilemma Score. The lower the score on this scale ‘the better the solution’ to the Energy Trilemma.
This paper outlines the Trilemma Scale methodology and compares Trilemma Scores for a range of technologies.

Comparison of a range of low emissions technologies including renewables (intermittent and firm), existing and new-build conventional power plants (coal and gas) and CCS (new-build and retrofit, with and without partial capture) is presented. Technologies and data sources were selected based on application in the Australian context.

The initial analysis aggregates the defined performance characteristics of each technology on an equal weighting however a range of sensitivities were also conducted to demonstrate the robustness of the findings.

The findings for the current performance criteria of technologies examined are outlined in the figure below. The Trilemma Score (TS) was also calculated using data projections that incorporate anticipated cost reductions and technology development for 2030.

![Trilemma Scale - Now](image)

- Of the unabated options, new-builds do not appreciably improve the TS as they trade off minor emissions reduction with higher levelised cost of electricity (LCOE) and the reliability is unchanged.
- CCS can improve the TS considerably in all cases although, of the new-builds with CCS, Natural Gas Combined Cycle (NGCC) is the only one to enter the top five (LHS of the graph).
- Firm renewables greatly improve the positioning from intermittent renewables, however the current high cost fails to see them in the top five.
- The top five technologies (LHS) are all fossil fuel related; one being existing NGCC, four include CCS, three of which are retrofit – one to gas and two to brown coal.
- There is a mismatch between current policy approaches and the TS. Significant focus and funding is being given to intermittent renewables and open cycle gas technologies (RHS of the graph) which rate poorly as contributors to the Energy Trilemma.

Interestingly, even in the 2030 case, CCS related technologies, particularly retrofit (with and without partial capture), remain the preferred solutions to the Energy Trilemma.
Funding support, investment and rhetoric to address the future energy mix is heavily directed to technologies that score poorly on the Trilemma Scale and little consideration is given to those that score favourably. At the very least, these findings should stimulate debate and consideration of investment and commercialisation incentives for a range of low emission options that include CCS.


