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# Evaluation of power investment decisions under uncertain carbon policy: A case study for converting coal fired steam turbine to combined cycle gas turbine plants in Australia

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## HIGHLIGHTS

- Policy uncertainty effects quantified in Australian power generation investments.
- A decision criterion provided to recommend optimal investment timing.
- The Clean Energy Act 2011 and high carbon price policy scenarios investigated.
- Post- implementation policy uncertainty creates disincentive for policy objectives.
- Setting a higher carbon price may dampen effects of political uncertainty.

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## ABSTRACT

Greenhouse gas (GHG) intensive fuels are currently a major input into the Australian electricity sector. Accordingly, climate change mitigation policies represent a systematic risk to investment in electricity generation assets. Although the Australian government introduced carbon pricing in 2012 and announced a commitment to the continuation of the Kyoto protocol beyond 2012, the opposition at the time signalled that should they be provided the opportunity they would repeal these policies. This paper uses a real options analysis (ROA) framework to investigate the optimal timing of one potential business response to carbon pricing: investment in the conversion of coal plant to lower emission CCGT plant. An American-style option valuation method is used for this purpose. The viewpoint is from that of a private investor assessing three available options for an existing coal plant: (1) to invest in its conversion to CCGT; (2) to abandon it, or; (3) to take no immediate action. The method provides a decision criterion that informs the investor whether or not to delay the investment. The effect of market and political uncertainty is studied for both the Clean Energy Act 2011 (CEA) and high carbon price (HCP) policy scenarios. The results of the modelling suggest that political uncertainty after the implementation of carbon pricing impedes the decision to switch to cleaner technologies. However, this effect can be mitigated by implementing higher expected carbon prices.



## 1. Introduction

With a scientific consensus having formed over the direction and factors that cause global climate change [1], many jurisdictions have implemented policies that promote a reduction in GHG emissions. However, much uncertainty still remains in terms of the range of possible policy responses to the problem. The non-cooperative game nature of global GHG mitigation agreement has accentuated the uncertainty of national policies. Therefore, contemporary energy supply investment is exposed to climate change policy risk in addition to traditional risk factors. Emission trading schemes (ETSs) have been designed and implemented to achieve least cost GHG reductions in order to encourage investment in cleaner technologies. However, given the aforementioned policy risk and its potential impact on carbon and energy prices, it is not only current policy settings but also expectations over future policy settings that will influence current investment decisions in long-lived carbon price exposed assets.

The principle aim of this study is to develop an investment decision making framework that incorporates the market and political uncertainty over future carbon prices and the value of waiting until such uncertainty recedes. A case study is developed to evaluate the

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timing of hypothetical brown-field conversion from an existing coal-fired steam turbine (CFST) to a CCGT plant in New South Wales, Australia.[1] The objective is to measure the influence of current ETS design, and uncertainty surrounding the policy's future, on that decision. Given that a substantial proportion of the capital cost of incumbent coal plants are sunk, their early scrapping and replacement with new low-emission technologies is a costly option. Therefore, brown-field augmentation of CFST with gas turbines, to benefit from a lower emission intensity and higher energy conversion efficiency, is potentially attractive as a means of preserving some of the asset value that was sunk into the original investment.

The case study emphasises two major sources of uncertainty associated with Australia's ETS: market driven carbon price volatility, and political uncertainty over the potential for the policy's repeal, with a focus on the latter. The future of the CEA policy in Australia is still under debate, and will be determined in part by the make-up of both houses of the federal parliament after a national election in late 2013. This paper presents a set of results, and their implications, stemming from the modelling of these uncertainties in the context of the aforementioned investment decision. The method used is real options analysis (ROA). In the face of current political uncertainties, investment decisions cannot be solely based on traditional discounted cash flow (DCF) analysis; investors may select to delay the decision rather than making an immediate decision as implied through the use of the DCF technique. Unlike DCF analysis, ROA explicitly accounts for both the value of waiting for more information and the opportunity cost of delaying an investment. This enables the analyst to make a judgement as to the best timing of investment, particularly where cost irreversibility and uncertain payoffs are significant.

Real options theory has been successfully applied in electricity market policy evaluation in two major inter-related research streams: (1) studies that consider a firm's decision to invest in generation technologies in a single-investment framework, and (2) a firm's decision to invest in a portfolio of generation technologies. In research stream (1) Dixit and Pindyck [3] have presented by a simple example how ROA can support taking decisions in electricity planning. Other studies such as Tseng and Barz [4], Deng and Oren [5], and Reuter et al. [6] have focused on operational variability and/or constraints on investment decisions within a short-term horizon. In a recent study, Reuter et al. [7] have compared greenfield investment in wind with coal plants. A subset of studies has shown interest on retrofitting incumbent coal-fired generation with carbon capture and storage (CCS). Reedman et al. [8], Reinelt and Keith [9], Fuss et al. [10,11], Szolgayová et al. [12], Zhou et al. [13], Zhu and Fan [14], and Zhang et al. [15] have developed case studies to investigate investment into CCS assuming exposure to market and/or political uncertainty. In research stream (2) numerous portfolio optimization studies in the electricity generation sector integrate the real options elements with either a myopic mean–variance portfolio optimization or a dynamic stochastic optimization framework. The standard deviation of the payoffs for investment alternatives, value at risk (VaR) or conditional value at risk (CVaR) are common risk measures applied in the relevant problem formulations. In more recent works, Fortin et al. [16] and Fuss et al. [11] have developed a static model on a portfolio of various generation technologies. Szolgayová et al. [17] have tried to extend the static portfolio problems to a dynamic formulation. Kumbaroğlu et al. [18] have integrated ROA approach within a deterministic optimization of the generation mix. A recent study of a dynamic portfolio of generation technologies has been conducted by Min and Chung [19]. They have employed CVaR in designing variability to consider rare events with enormous effects and have found that liquefied natural gas (LNG) or coal can be secure candidates for Korea to reduce its dependency on nuclear energy. Many authors in this research stream combine a present value analysis of costs or benefits with a measure of risk in the relevant objective function used in a stochastic optimization framework under uncertainty.[2]

This paper focuses on research stream (1) as described above.[3] Addressing some of the knowledge gaps in the existing literature, this is the first study, to our knowledge, that models the relationship between the carbon price level and political uncertainty in a post-implementation framework, i.e. with a carbon price scheme already operating. In addition, we focus on the conversion of CFST plants to CCGT since it is a readily available technology. Moreover, in this conversion process, some of the sunk cost of original investment into CFST plant can be preserved. The novelty of our research lies in: (1) simulating electricity price paths based on Treasury forecasts, (2) presenting a new metric, option value ratio (OVR), to assist in determining which investment decision and timing is likely to be most profitable in the presence of uncertainty, and (3) modelling the salvage value of the incumbent CFST plant as a function of the probability of repeal and the corresponding expected repeal times. A comparison of the investment value calculated by standard DCF and ROA methods, along with the value of flexibility, provides the aforementioned OVR decision criterion that can assist the decision over whether or not to delay the investment.

Among numerous works applying ROA, the most relevant studies to the current analysis are those of, Reedman et al. [8], Laurikka [20], Laurikka and Koljonen [21], Blyth et al. [22], Fuss et al. [10], Zhou et al. [13], and Szolgayová et al. [12]. These authors have investigated the effect of various carbon pricing mechanisms on investment decisions in the electricity sector by implementation of specific scenarios and/or sensitivity analyses.[4] The only Australian study among these by Reedman et al. [8], developed a real options model to evaluate the timing of the uptake of a natural gas fuelled plant and various coal technologies, as well as the retrofit of carbon capture facilities in existing plants. However, conversion of an existing coal plant to a CCGT using pre-existing technology was not modelled. They found that the investor's perception of carbon price uncertainty has significant influence on investment decisions, even before the actual enactment of carbon price legislation. Our analysis considers risk in the opposite direction, that of uncertainty over the repeal of existing legislation.

The model formulation developed in this paper conceptually builds on the Dixit and Pindyck [3] dynamic programming approach, draws on International Energy Agency (IEA)'s real options methodology [22] and uses the Monte Carlo simulation type least-squares method developed by Longstaff and Schwarz [24] to value an 'American'-type option.[5] Investment risk evaluation with the real options methodology provides important capabilities, such as separate and integrated elements of risk modelling to assess their relative contribution to overall risk [22].

## 2. Model

This work takes the view of a private investor. It is assumed that a 400 MW coal-fired steam turbine power plant has been running

[1] Electricity generation in Australia, which makes use of abundant coal resources, is responsible for over a third of the country's GHG emissions [2].

[2] For a detailed literature review of long-term electricity planning refer to the recent study by Min and Chung [19].

[3] The focus of this paper is on a single investment decision. An extension of the model to implement a portfolio of generation technologies is currently under consideration.

[4] For a more detailed review of the application of real option analysis in the electricity sector refer to Fernandes et al. [23], Blyth et al. [22].

[5] An 'American'-type option refers to a type of option in which the option can be exercised at any time during its life.