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Cooperative bargaining of Australian coal plants under a regulatory threat

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Abstract

The energy market in Australia and particularly the state of Victoria, finds itself in a precarious, transitional state. Researchers have concluded that barriers to orderly exit are present for highly-polluting and aged incumbent brown coal generation, further preventing renewable generation from entering the market (Riesz & Noone, 2013; AEMC, 2015a; Frontier Economics, 2015). Faced with oversupply of generating capacity and the unwillingness of the government to adopt a first-best carbon price, a variety of second-best measures have emerged attempting to achieve an emissions-efficient retirement and help Australia reach its ratified emission targets (Caldecott *et al.*, 2015; Jotzo & Mazouz, 2015; Nelson *et al.*, 2015). This paper aims to investigate the usefulness of a cooperative bargaining mechanism under the threat of an emissions performance standard (EPS), for two of the most emission intensive generators in the National Electricity Market. We estimate the expected income for the generators over their expected lives under differing EPS stringencies from a base case scenario. Utilising Nash Bargaining, it is determined whether an agreement can be reached for one to pay the other to retire. The power plants choose between lowering output ('mothballing' capacity), or installing carbon capture and storage facilities (CCS) in order to comply with the regulation. We finally introduce expectations of regulatory uncertainty to examine the effect on previous outcomes.

The findings indicate that implementing a modest but credible threat of a 1.1t CO_2-e/MWh could theoretically achieve a plant exit. High decommissioning and rehabilitation costs prevent weaker and more politically acceptable emission standards succeeding. The owners select mothballing of capacity over the high investment costs and inefficiencies associated with CCS to adhere to the regulation when bargaining fails. When introducing regulatory uncertainty with the outcome, the agreement is expected to fail if plant owners expect the policy to be ineffective on profits for more than 51% of the time.

Sammanfattning

Energimarknaden i Australien och särskilt i staten Victoria befinner sig i en osäker övergångsperiod. Forskare har konstaterat att barriärer existerar som gör det svårt för högförorenade och åldrande brunkol att upphöra brukas, vilket motverkar den nya generationens förnybara energikällor från att inta marknaden (Riesz & Noone, 2013; AEMC, 2015a; Frontier Economics, 2015). Ett överutbud av produktionskapacitet tillsammans med regeringens ovilja att sätta ett pris på koldioxidutsläpp, medför att reglerande ingrepp är behövda för att uppnå en utsläppseffektiv stängning av den äldre generationen, vilket skulle hjälpa Australien att uppnå sitt utsläppsmål från klimatmötet i Paris 2015 (Caldecott *et al.*, 2015; Jotzo & Mazouz, 2015; Nelson *et al.*, 2015). Denna forskning strävar mot att förse en fallstudie för att undersöka användbarheten av kooperativa förhandlingar under hotet av EPS (Emissions Performance Standard) på två av de mest förorenade i den Australienska energimarknaden. Vi uppskattar den förväntade inkomsten för kolkraftverken under deras livslängd under olika stringenser av EPS och ett basfallscenario. Därefter utnyttjar vi Nash Bargaining för att avgöra huruvida en överenskommelse där ett kolkraftverk betalar ett annat för att lämna marknaden kan uppnås. Kolkraftverken väljer mellan att sänka produktionen (’mothballing’), eller att installera koldioxidfångning och lagring (CCS) för att följa regleringen. Slutligen undersöker vi detta med ett tillsatt inslag av osäkerhet i regeringens politik för att undersöka effekten av tidigare resultat.

Resultaten indikerar att implementation av ett måttligt men trovärdigt hot av 1,1 ton CO2-e/MWh kan teoretiskt sett medföra att ett kolkraftverk försvinner från marknaden. Höga kostnader för avveckling och restaurering förhindrar svagare och mer politiskt acceptabla utsläppsstandarder från att lyckas. Ägare av kolkraftverk väljer till övervägande del ’mothballing’ av kapaciteten över de höga investeringskostnaderna associerade med CCS för att hålla sig fast vid regleringen då ett icke-avtal uppstår. Om ägarna förutsätter att policyn kommer att vara ineffektiv för vinster mer än 42% av gångerna, kommer i sin tur avtal att misslyckas, vilket bekräftar behovet av tydliga och trovärdiga policys för utsläpp från regeringen (Nelson *et al.*, 2015).

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Abbreviations and Acronyms

AEMO	Australian Energy Market Operator
CCA	Climate Council of Australia
CCS	Carbon Capture and Storage
COAG	Council of Australian Governments Energy Committee
EPS	Emissions Performance Standard
ERF	Emission Reduction Fund
ETS	Emission Trading Scheme
FOM	Fixed Operating and Maintenance cost
GJ	Giga-Joules
H, Y	Hazelwood, Yallourn (power plants)
HHV	Higher Heating Value (thermal efficiency)
LCOE	Levelised Cost of Electricity
LRET	Large-scale Renewable Energy Target
LV	Latrobe Valley
MWh	Mega-Watts per Hour
NBS	Nash Bargaining Solution
NEM	National Electricity Market
NPV	Net Present Value
SCPC	Sub-Critical Pulverised Coal Power Plants
SRMC	Short-run Marginal Cost
tCO_2-e/MWh	Tonnes of CO_2 emitted per Mega-Watt hour of electricity sent-out
VA	Voluntary Agreement
VOM	Variable Operating and Maintenance cost

1. Introduction

The previous Australian government was celebrated for their world-leading climate policy when they introduced a national carbon tax on emissions in mid-2012. It was envisioned to transition into an emission trading scheme, to eventually be linked with other schemes throughout the world. Once implemented, Australia's electricity generation from its traditional fleet of coal-fired generation dramatically declined. Forced to incorporate the social cost of their emissions into their production decisions, owners instead chose to retire generation or mothball[1] capacity (King, 2015). Their removal from the energy mix was largely replaced by cleaner generating technologies such as renewables whose cost competitiveness had dramatically improved. The achievement was short-lived, with the tax was repealed by the successive centre-right party that came to power (Department of the Environment and Energy, 2013). Since its removal in mid-2014, coal-fueled power generation has once again increased along with their associated emissions, as mothballed coal generation has been brought back into operation (Figure 1.1). The reversal halted further investment in renewable technologies, whose levelised cost of electricity (LCOE)[2] is much higher than incumbent coal when not made to account for their emissions (EPRI, 2015). This contributed to the government reducing the LRET[3] which subsidses zero

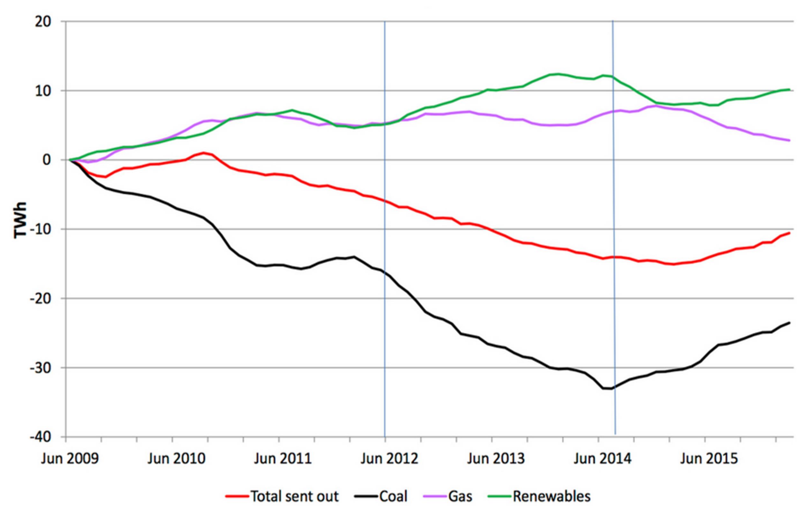

Figure 1.1 – Recent Changes in Electricity Generation in the NEM
Source: Saddler (2016)

[1] To reduce the plant's output and operational costs by temporarily shutting down units of the total capacity.
[2] The levelised cost of electricity is a decision making tool that incorporates all the costs of a plant from initial investment to shut down compared with the MWh they can produce.
[3] The mandated Large-Scale Renewable Energy Target was reduced from 41000GW to 33000GW in 2015.

emission technologies for large-scale power generation (Nelson *et al.*, 2015).

The 2015 Paris Climate Agreement recently led to the establishment of Australia's CO_2 emission reductions targets of 26-28% below 2005 levels by 2030 (Department of the Environment, 2015). The Australian government has repeatedly expressed their lack of support for a price on carbon (Anderson, 2016), adamant that their environmental policy suite, 'Direct Action Plan,' will be capable to achieve the required reductions. Given their repeal of the previous government's carbon tax it is hardly surprising, as backtracking provides major political problems. Despite this, there is mounting evidence projecting Australia will fail to meet these emission targets by a substantial margin given current emissions policy (Rocha *et al.*, 2015; The Climate Institute, 2016).

1.1 Victorian Brown Coal Generation in the NEM

The Australian National Electricity Market (NEM) is one of the largest interconnected electricity grids in the world, covering all Australian States except The Northern Territory and Western Australia. It represents a wholesale market for the supply of electricity through distribution networks across the states from generators to retailers and end-users, accounting for 90% of Australia's total electricity generation (AEMO, 2010). To supply the electricity in the market, the Australian Energy Market Operator (AEMO) collects bids from the generators in ascending price order[4] for each dispatch period. Generators are then progressively scheduled to supply their electricity up to a point where cumulative supply of the bids meets the overall demand, with the final accepted bid setting the wholesale price of electricity which all generators receive (*ibid*).

Australia has historically been heavily reliant on fossil fuels for electricity production, with more than 90% coming from coal, gas and oil. The Latrobe Valley (LV) lies in the Gippsland region of Victoria, home to one of the largest brown coal deposits in the world, with an estimated 33 billion tonnes of economically viable brown coal remaining (MCA, 2014). As a result, electricity generation in Victoria has been traditionally dominated by an ageing fleet of sub-critical pulverised coal (SCPC) power plants utilising this fuel source. They have been shown to supply a baseload[5] close to 50% of the state's electricity (Caldecott *et al.*, 2015). This fuel source is very cheap but has a very low energy content, producing higher greenhouse gas emissions than other

[4] This is known as the 'merit order'.
[5] Constantly operating the power plants to be included in the energy mix for all levels of demand.

forms when used in energy production (MCA, 2014). The combination of these ageing, inefficient plants fueled with highly-emitting brown coal, equates to these plants having some of the highest emission intensities[6] in the OECD (WWF, 2005).

Two of the highest emitting (Hazelwood and Yallourn) are vertically-integrated, owning both the power plant and their nearby mine from which they are sourced. With their 35+ year facility's already paid off, their short-run marginal costs that dictate production decisions are often simply a function of their fuel costs (Ward, 2015). These extremely low operating costs mean that their bids to supply their electricity will almost always be accepted into the energy mix. In contrast to this when the carbon tax was in effect, it was estimated that these generators were operating close to break-even when excluding transitional support provided by the Australian government (Ward, 2015). LCOE projections to 2030 show that renewables will be competitive with CCS technologies, but marginally on par with non-CCS fossil fuel technologies with no carbon price (Brinsmead *et al.*, 2014). Without a carbon price, it can be expected that these highly emitting brown coal plants will be cost effective up until the end of their expected plant lives into 2030.

1.2 Problem Statement

In the last decade, the NEM has been faced with the problem of increasing overcapacity[7] of generation as the demand for electricity has gradually fallen (Nelson *et al.*, 2015). This has been attributed to factors like energy efficiency programs, structural change, and the response of electricity consumers to price rises such as increased uptake of residential solar (*ibid;* Saddler, 2015). Exacerbating this oversupply is the addition of renewable energy in line with the government's Large-Scale Renewable Energy Target (LRET) (Jotzo & Mazouz, 2015; Nelson *et al.*, 2015).

With no carbon price, an ageing fleet of emission-intensive brown coal plants enjoy high capacity factors (the percentage of their capacity utlilised), when not made to account for the social cost of their emissions (Ward, 2015). Furthermore, multiple barriers to exit have been identified for the incumbents further preventing efficient exits (AEMC, 2015a; Frontier Economics, 2015; Nelson *et al.*, 2015). Instead, a disorderly exit is taking place in response to

[6] This refers to tonnes of CO_2 emitted per MWh of electricity sent-out or sold.
[7] The AEMO (2014) identified overcapacity of 2000-2200MW in Victoria where the LV power plants are based, and around 7,600MW for the entire NEM – recently supported by King (2016).

the overcapacity, with technologically more efficient, lower-emitting black coal plants being forced to retire or mothballed (Riesz & Noone, 2013).

On Australia's current emissions trajectory, an 82MtCO2e abatement gap has recently been identified to meet the 2030 emissions target (Climate Works, 2017). With a lack of effective emissions regulation for the electricity sector, commentators have recognised the need for an orderly brown coal phase-out plan, to allow for the transition to a cleaner electricity system (Caldecott *et al.*, 2015; Denis *et al.*, 2015; Jotzo & Mazouz, 2015; Nelson *et al.*, 2015; King, 2016). With an outlook of flattening demand (AEMO, 2016) and oversupply to be stretched by further additions of renewable supply in accordance with the RET, intervening for a plant exit is not seen to pose a threat to the security of the electricity supply in the short run (Nelson *et al.*, 2015).

1.3 Objective and Hypothesis

The main aim of this study is to determine whether cooperative bargaining will provide a solution to retire a highly-emitting lignite power plant under the threat of an emissions performance standard. Different stringencies of standards will be used to identify the setting that is optimal for the regulator to achieve an exit. Optimal abatement strategies between reducing output, or installing carbon capture and storage facilities will be determined in order to meet the regulation under disagreement. Finally, uncertainty is introduced over the regulation's credibility to examine the effect this has on the outcome reached previously. If an agreement is reached, we expect more stringent standards to require less credibility when uncertainty is introduced for the agreement to be maintained. Due to the low take-up of CCS being in its infancy stages, we expect the cost will be too high compared with reducing output as has been observed in reality.

1.4 Outline

A review of literature on barriers to exit for the studied plants, the question of intervention and regulatory proposals is provided in Chapter 2. Chapter 3 will discuss cooperative bargaining and voluntary agreements, moving into the Nash Bargaining framework. The data, components and methodology of the cooperative bargaining game will be covered in Chapter 4, with the results and a discussion presented in Chapter 5. The main findings of the paper will be concluded in Chapter 6, with chapter 7 addressing areas of concern for further research.

2. Literature Review

A lack of effective emissions regulation for the electricity sector has led to discussion over apparent 'barriers to exit'[8] for highly-emitting brown coal generation and the question of intervention (Frontier Economics, 2015; Nelson *et al.*, 2015; King, 2016). AEMC (2015) claims that despite their existence, these barriers to exit have not deterred generators from exiting, and it should be left to the market to determine which plants should exit. This notion is supported by COAG (2014) who argue that intervention can be seen to transfer retirement costs on to consumers and tax-payers. However, the Senate Committee (2017) importantly acknowledged that although exits are still occurring in response to market signals, these barriers are problematic as they cause 'disorderly exits'[9], and support the investigation of policies to induce an exit.

2.1 Barriers to Orderly Exits

With high sunk costs of capital intensive plants, and low SRMCs to determine operating decisions, plant owners have more flexibility in their level of output, and are able to see out periods of low demand better than higher-cost but technologically more efficient generators (Riesz & Noone, 2013). Compounding this is the presence of a 'first mover disadvantage' for the incumbents (Lieberman & Montgomery, 1988). Despite market signals of overcapacity and reduced demand, they hold out in the hope of a competitor deciding to retire, leading to benefits from expected increases in wholesale prices and their own output to cover the lost supply (Nelson *et al.*, 2015). This is seen to have flow on effects, creating barriers to entry for new entrant renewable generation (Jotzo & Mazouz, 2015).

Uncertainty over the expectantly sizeable decommissioning and rehabilitation costs at the retirement of the 35+ year plants and their mine sites is expected to constitute a further barrier (Environment Victoria, 2014). These costs are expected to exceed provisions made by their owners to meet the required clean-up by hundreds of millions of dollars (King, 2016), attributed to provisions being made on incorrect assumptions and the lack of regulatory obligations for the firms in meeting these costs (AEMC, 2015a). This leads to the plants delaying their exit in order to avoid fronting up to these costs for as long as possible. Recommendations from a recent senate

[8] Defined as costs or foregone profits that a firm must bear if it leaves an industry," (AEMC, 2015a).
[9] This refers to the retirements of newer and lower-emitting generation over technologically less-efficient and higher-emitting ones.

committee have called for a national audit on these costs, as well as a common approach to setting rehabilitation bonds to ensure costs are properly provisioned for (Senate Committee, 2017). Further uncertainty surrounding the future direction of emissions regulation[10] has created mixed-messages for plant owners on how to invest for the future (Nelson *et al.*, 2015; Slezak & Farrer, 2016). This lack of clear policy direction has increased the 'option value' of waiting to determine future market conditions and regulation in the industry (Riesz & Noone, 2013). Nelson *et al.* (2015, 26) states the importance of clear articulation of the reasons for new policy to promote credibility.

2.2 Government Emissions Policy

It is seemingly clear that there are multiple forces all working to prevent an orderly exit of the aged generation capacity. The repealed carbon tax was estimated to come closest to accurately estimating the social costs of emissions of the Latrobe Valley plants, but still fell well short (Ward, 2015). Despite this, the brown coal generators of the Latrobe valley received assistance from the 'Energy Security Fund,' created to assist heavily impacted industries at its introduction, and avoid risks to energy security. The assistance has been since deemed unnecessary as security risks were actually relatively low (Mountain, 2013). Furthermore, the LV plants were calculated to have passed on 111% of the cost of the carbon tax to consumers which was much higher than forecast, so the assistance instead became additional profits for the plants (*ibid*).

Since it's repeal, the succeeding government's emission reduction policy is centered around the 'Emission Reduction Fund (ERF),'using a reverse-auction mechanism to identify lowest-cost emission reduction projects for public funding (Department of the Environment, 2015). The policy has been heavily criticized for ignoring Australia's fossil fuel-reliant energy industry (Jackson, 2014; King, 2016) which contributes 36% to Australia's total carbon emissions (Department of Resources, Energy and Tourism, 2010). Instead, winning lowest-cost bids are often focused around land reorganisation activities (such as afforestation)(CER, 2017a). Burke (2016) also raises serious concerns over its susceptibility to problems of adverse selection (Akerlof, 1970), where a project would have occurred regardless of the government paying for the reduction. Reductions purchased are protected by a 'Safeguard Mechanism,' ensuring other industries do not increase emissions above historical business as usual levels (AEMC, 2015b).

[10] Such as the repeal of the carbon tax in 2014 and the failed payments for closure campaign of 2012.

However there have been revelations of serious flaws, with Environment Victoria (2015) calculating that emissions from coal fired power stations alone could theoretically increase 40-50 million tonnes without it breaching the mechanism.

The main policy targeting the electricity sector focuses on increasing Renewable energy, designed to complement the ERF and reduce emissions in the emission intensive electricity sector. The Large Scale Renewable Energy Target (LRET) originally mandated an amount of 41000 GWh of additional renewable electricity generation by 2020, to achieve 23.5% of Australia's energy from renewable sources (CER, 2017b). However falling demand for electricity and barriers to exit for coal incumbents caused overcapacity in the market, with the target was scaled back by 8000GW in 2015 *(ibid)*. The original target was criticised for being set with little analytical rationale (Wood & Mullerworth, 2015), and that fixed additions of renewable generation to an oversupplied system do not incentivise an efficient energy mix (Nelson *et al.*, 2015). Consequently, this regulatory uncertainty has served to exacerbate barriers of regulatory uncertainty for aging brown coal incumbents. There are growing calls for it to be developed past 2020 with bipartisan support, with clear rationale to achieve credibility of the policy and reduce uncertainty (Wood & Mullerworth, 2015; Senate Committee, 2017).

2.3 Intervention for an exit

The presence of barriers to exit for the ageing incumbents is widely accepted, and with lack of effective environmental policy targeting their emissions, there is mounting support for intervention to promote orderly and cost-effective exits. The first-best policy intervention is widely considered to be a price on carbon, creating a market to efficiently price the cost of abatement, and generate government revenue to reduce pre-existing distortionary taxes and compensate heavily affected industries (Parry *et al.*, 1997). Market mechanisms are able to uncover information asymmetries and therefore achieve targets more efficiently at lower cost than direct regulation (Jotzo & Mazouz, 2015).

A cap and trade or emission trading scheme known as the 'Carbon Pollution Reduction Scheme,' was failed to be implemented by the previous government in 2009 (Taylor, 2010). It was expected to have delivered the most efficient emission reductions in a more politically acceptable form than that of a carbon tax (Weller, 2012). Their usefulness to cost-effectively reach emission goals is demonstrated in the Climate Institute (2016) report, estimating that a modest carbon price rising to $40 by 2030 would be sufficient to achieve the 2030 emissions target. Recently, an Emission Intensity Scheme was propose by the Opposition in the lead up to the 2016 Federal Election (Australian Labour Party, 2016), and was the option ultimately recommended in the special review report by the CCA (2016). It sets a baseline emission standard that all generators must adhere to, similar to an emission performance standard across the industry, each issued with permits for their allowed emissions in line with the baseline on BAU generation. Those who are under the baseline can sell to those that are over, creating a market to trade certificates and an explicit price on carbon.

Despite these options offering efficient societal outcomes of lowest cost abatement, the current government have publicly stated that they will not pursue a price on carbon (Packham & Kaye, 2016). This could be expected to stem from the political issues of backtracking on their repeal of the previous government's price on carbon. Considering this, various second-best forms of intervention have emerged to achieve an orderly exit. Each needs to overcome hurdles of information asymmetry and questions of compensation size, while ensuring minimal impact on tax-payer funds and retail price rises (Jotzo & Mazouz, 2015).

A pure or direct regulatory approach could be taken upon emission intensive power plants to police their emissions and possibly induce an exit. This may be in forms such as Emission Performance Standards on incumbents like the government's policy for emission standards on new coal-fired generation (Department of Resources, Energy and Tourism, 2010), mandating CCS on plants above a certain age or emission intensity (Johnson *et al.*, 2015; CCA, 2016), or mandated closures based on age over a set period of time (Caldecott *et al.*, 2015). These all require regular monitoring and compliance costs incurred by the regulator. However the main issue faced by the regulator are the information asymmetries to induce an cost effective retirement (Jotzo & Mazouz, 2015). While it can achieve significant emission reductions, the asymmetry can affect the correct level to set the regulation for efficient outcomes. Furthermore they are unlikely to impose the full cost of early closure on individual plants due to the current political climate *(ibid).*

The COAG energy council considered re-visiting the previous government's failed 2012 'Payment for Closure' program (COAG, 2014) which aimed to facilitate the orderly exit of 2000MW of highly emitting coal capacity (Riesz & Noone, 2013, p 9) . Closures are negotiated between the government and power plant owners through compensation for future foregone profits. A similar scheme has been approved by the European Commission to regulate out German lignite power plants over the next few years (European Commission, 2016). The Australian government's program was plagued by information asymmetries between the government and the power plants and negotiations failed (Riesz & Noone, 2013). It also struggles with political acceptance of large payments of public funds to owners of old emission intensive power stations (Jotzo & Mazouz, 2015). Furthermore, it is criticised as creating a vicious cycle of expectations of future payments, creating barriers to exit for incumbents, and insignificant reductions in emissions due to another highly-emitting plant taking the exited plant's place (Riesz & Noone, 2013).

The CCA (2016) has recently recommended adopting a market mechanism for the electricity sector due to their ability to be scalable and flexible. Incorporating elements of direct regulation leads to hybrid alternatives, which can still retain flexibility and efficiencies of market mechanisms.

Caldecott *et al.* (2015) proposed publicly funded, time-lined closures operating in tandem with new emissions regulation on the plants. The regulation reduces compensation required as the new regulation limits owner expectations of future profits as well as targeting oldest plants first who have paid off their plants and are at the end of their technical lives (p.12). However it did not deal with the problem of covering the decommissioning and rehabilitation costs required to be paid to induce a closure. It also exacerbates the problem of incumbents holding out in anticipation of further compensation associated with publicly funded closures (Riesz & Noone, 2013, p 20). It has been expressed by the COAG Energy council that they do not support assistance to generators for retirement (COAG, 2014, p 1).

A reverse auction mechanism is briefly introduced by Caldecott *et al.*(2015) as an alternative and cost-effective way to retire SCPCs, whilst uncovering some information asymmetry between the owners and the regulator. Owners bid to receive a fixed price for each unit of generation capacity retired, with the lowest bid winning the auction. Jotzo and Mazouz (2015) have recently proposed a mechanism where generators secretly bid in this style for a mandated amount of their capacity to be closed. In contrast to Caldecott *et al.* (2015), payment includes a portion to cover expectantly large costs to retire operations and rehabilitate the plant and mine. The winning bid is funded by the remaining generators proportional to their emissions. The authors argue that this will avoid the barrier to exit of publicly funded payments for closure schemes, but questions still remain over plants employing non-competitive bidding practices to reduce bid values and corresponding funding required, as well as levels of cost-pass through *(ibid, p.11)*.

This study proposes a fusion of these two hybrid mechanisms. Similar to reverse auctions but using a cooperative bargaining with only two players, it proposes to also avoid issues of information asymmetries for the regulator on compensation required and incorporate decommissioning and rehabilitation costs (the true extent of which are unknown to the public), whilst avoiding public funding and costs to the tax payer. It will avoid issues of colluding among the plants raised in Jotzo and Mazouz (2015)'s non-cooperative mechanism, but also incorporates the direct regulatory threat of an EPS to help limit required compensation in Caldecott *et al.* (2015). Moreover, this paper will take the further step of modelling expected profits to ascertain the settings under which a plant exit is likely to be achieved.

3. Conceptual Framework

Arimura *et al.* (2008) states that voluntary agreements (VAs) have been shown to be useful tool when there is opposition to the introduction of first-best policies, and in favourable conditions are able to achieve similar abatement levels (Schmelzer, 1999). The following section will look at the merits of cooperative bargaining to reach an agreement, following with the game theoretical framework of Nash Bargaining (Nash, 1950).

3.1 Cooperative Bargaining

A bargaining situation arises when a pair of players can engage in mutually beneficial trade faced with conflicting interests, but have a common interest to cooperate (Muthoo, 2001). VAs are suggested to be more flexible, effective and less costly than traditional command and control approaches (Arimura *et al.*, 2008). Conditions for this usually depend on perfect information, credible threats of regulation, having one period of negotiations, and only one abatement technology (Schmelzer, 1999).

An agreement will be in the firms best interest to do so, as profit motivated firms make voluntary agreements to avoid costs of regulation (Carraro & Leveque, 2013). This is combined with the benefit to the regulator avoiding compliance and enforcement costs for the mandatory abatement, increasing social benefits (Krarup, 2001). However for the VA to be a useful tool for the regulator, any agreement reached in emission reductions should not exceed emissions if subjected to the regulation (Schmelzer, 1999).

Most research centers around VAs between firms and the state, demonstrated in Schmelzer (1999), with the state agreeing not to regulate by imposing standards on their emissions. The VA in our study will be between two highly-emitting power plants, with an agreement characterised by one compensating the other for retiring from the market. In this form, there is no compensation with public funds as with ‘payment for closure’ schemes. Where information is not perfect, Krarup (2001) notes that a crucial condition for efficiency of a VA depends on its ability to uncover information asymmetries for the regulator. The power plants can be expected to have symmetric information of one another due to their similar profiles, to a higher degree to what the regulator may be expected to have. This is further supported by detailed reputable reporting from government bodies and independent consulting groups (ACIL Tasman, 2009; ACIL Allen, 2013, 2014; AEMO, 2013).

Carraro & Leveque (2013) argue that environmental effectiveness of voluntary agreements is questionable in situations when the firms do not respect their targets or are set too low, drawing parallels with the importance of credibility of regulatory threats in Nelson *et al.* (2015). The EPS will be set lower than the plant's emission intensities, placing a constraint on operations and materially impact profit to a level dependent on the EPS's stringency. This credibility is also influenced by the monitoring and compliance effectiveness of the regulator under agreement and facing the regulation (Stranlund, 2010; Carraro & Leveque, 2013). If the exiting plant does not respect the agreement for closure, it will obviously be clear to the regulator. An agreed exit from the market should only require compliance surrounding the agreed timing of the exit. On the other hand for non-agreement, this is handled with the ongoing comprehensive monitoring and reporting as mentioned. It can be reasonably accepted that the plants will not be able to shirk on their responsibilities.

Krarup (2001) acknowledges that if a government is pro-firm and the firms have influence in the forming of regulation, environmental targets are susceptible to being lowered. In this case, a voluntary agreement may help to avoid a distorted piece of legislation for the government (Glachant, 2007). A VA may be a reasonable compromise to handle the state of 'political paralysis'(Weller, 2012, p 1262) in emissions policy for the Latrobe Valley, and Australian coal industry's lobbying power with the government. There is also the risk that a polluter will enter into negotiations for an agreement to delay the legislation due to the time it takes to implement and enact the legislation (Glachant, 2007). The period of the negotiations must be relatively short and avoid being prolonged. Nelson *et al.* (2014) emphasises this with the need of the regulator to move swiftly from announcement to implementation and minimise regulatory uncertainty.

A risk with VAs, as experienced with payment for closure schemes, is in how to avoid further expectations of compensation that strengthen barriers to exit (Riesz & Noone, 2013). Despite a voluntary agreement in our case referring to payment from another generator rather than public funds, this may still act to cause generators to delay exit and strengthening barriers to exit (Riesz & Noone, 2013). The regulator needs to send a clear message that this will be the one and only round of a regulated closure, involving the two highest emission intensive generators in the market. This message is supported by the degree of overcapacity in the market and will be almost eliminated by a closure in Victoria (AEMO, 2014), including the continuation of natural closures of generation capacity as a response to market signals.

Game theory has been shown to be a useful tool for investigating voluntary agreements, as it is founded on optimal decision making with rational agents (Schmelzer, 1999). We follow this with the framework of Nash Bargaining to study the cooperative bargaining problem.

3.2 Nash Bargaining

A two-person bargaining problem involving collaboration for mutual benefit can be modelled using Nash Bargaining (Nash, 1950) – using utility theory in a game theoretical context to bargain over a potential surplus between the two firms (Morgenstern *et al.*, 1953). Nash assumes the two players are highly rational, each can compare desires for various things, equality in bargaining skill, and full knowledge of tastes and preferences of the other.

In our bargaining game, the two firms who own the power are profit maximizing entities and can therefore be considered highly rational. Both generators have similar profiles that include the state of the technology used and it's efficiency, the location of the plants and the mine sites are in the same location, as well as regular reputable reporting from various government agencies on costing data and market changes. In this regard, both should have similar expectations of the other and are assumed to have complete information, including tastes and preferences and the ability to compare tastes and preferences of the other firm (Nash, 1950).

Nash (1950) idealises bargaining skill as being equal between the two generators. Both are large generators supporting a large work-force as well as acting as a commercial centre for the local community. Their close proximity with each other means this community impact is inter-twined. Both generators are considered highly-emitting, however Yallourn's emission intensity is marginally lower by 0.11t CO_2-e/MWh, and therefore 'cleaner' or more emissions efficient at producing electricity. In contrast with this, the Hazelwood plant operates a generating capacity that is 150MW greater than Yallourn's, and employs more workers and can be seen to have a higher community impact. We assume that these differences offset each other when examining bargaining skill within the confines of the bargaining game. In addition to this, there is a time allowed for the two generators to cooperate as set by the government. Therefore, neither has an upper hand over the other on a matter of time and patience which can lead to bargaining power (Muthoo, 2001).

Muthoo (2001) refers to a unique outcome for each bargaining situation in some class of bargaining situations. The solution of the bargaining problem will determine the amount of satisfaction each individual should expect from the opportunity to bargain, aiming to maximise the product of surplus utilities in the two-person bargaining game (Nash, 1950). If any surplus is found to exist, the bargaining solution will determine how this surplus will be split amongst the parties in the terms of the agreement (Anderlini, 2015).

To achieve this, Nash (1950) developed an axiomatic approach to bargaining, which abstracted away from the details of the process of bargaining and considers only the set of outcomes or agreements that satisfy the following reasonable properties; (i) the solution must be pareto-efficient, as an inefficient outcome would expected to lead to renegotiation, (ii) if everything is symmetric in the bargaining problem, the agreement should not discriminate and pick out a symmetric solution, (iii) a transformation of the utility functions of either player which maintains order of preferences should not alter the bargaining process outcome, and finally (iv) Independence or Irrelevant alternatives states that the optimal solution of a first set of possible agreements can ignore alternatives of a larger second set if, if this second set contains the entire first set and it's optimal solutions is the same as the solution of the first set.

A function that satisfies these axioms will pick out a unique solution from any 2 player $(i=1,2)$ bargaining problem $B = (U,d)$ where U is a convex and compact set of the possible agreements in terms of utilities for 1 and 2: $(u_1,u_2) \in U$, and d is a pair (d_1,d_2) resulting in the utilities for 1 and 2 from failure of the bargaining known as the 'disagreement point' with $d \in U$. There exists an agreement $u \in$ U for that $u_1 > d_1$ and $u_2 > d_2$ which ensures a mutually beneficial agreement.

The Nash Product devised by Nash (1950) is the furthest north-easterly hyperbola with asymptotes equal to the disagreement points of the two players, that touches the maximand of the bargaining set of possible utilities for the two individuals (Anderlini, 2015). The point where it touches will provide the Nash Bargaining solution (u_1^N,u_2^N) as shown in figure 3.1.

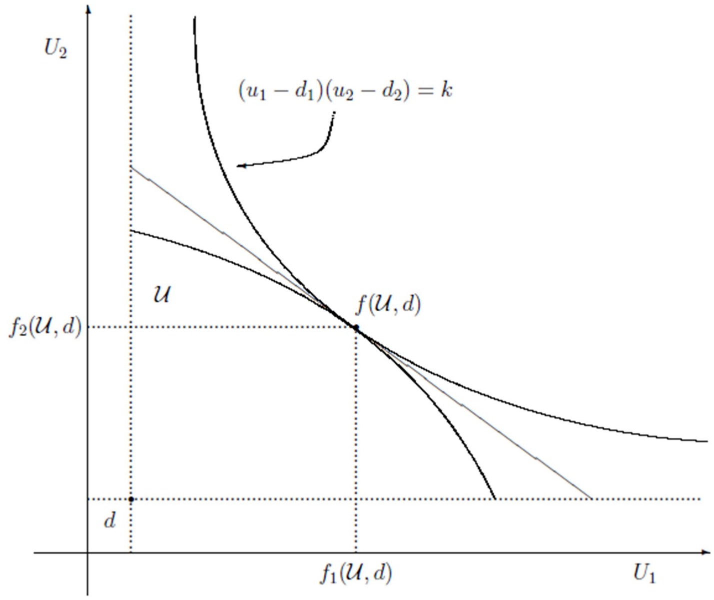

Figure 3.1 – A graphical representation of the Nash Bargaining Solution. Source: Anderlini (2015)

This is represented mathematically by the following constrained maximization problem:

$$\text{Max } (u_1,u_2): \quad (u_1 - d_1)(u_2 - d_2) \qquad \text{s.t. } (u_1,u_2) \in U \qquad (1)$$

As we have assumed that there exists symmetric information between the plants, a split the difference rule applies as shown in Muthoo (2001) where the parties receive the value of their disagreement points and agree to split the remaining surplus. π refers to the utility received for the player making the offer to the other. The utilities are then calculated as follows.

$$U_1^N = d_1^N + ½ (\pi - d_1 + d_2) \quad \text{and} \quad U_2^N = d_2^N + ½ (\pi - d_1 + d_2) \qquad (2)$$

With the assumptions made, Nash Bargaining can be idealised between the studied power plants, in order to find a mutually beneficial agreement that is the pareto-efficient outcome (Nash, 1950).

4. Model Specifications and Approach

4.1 Plant Profiles

Hazelwood and Yallourn[11] are the two of largest and most emission intensive power plants in the NEM, and are therefore chosen as the two plants to participate in our case study (WWF, 2005). They are both vertically-integrated mine-mouthed[12] operated power plants (Energy Australia, 2016; GDF Suez, 2016a) . Emission Intensities are calculated using emissions intensities based on electricity sent-out[13] data as opposed to electricity generated which includes electricity consumed by the plant for its operation (ACIL Tasman, 2016). Hazelwood operates with an emission intensity of 1.53t CO_2 per MWh sent-out and Yallourn with 1.42t CO_2 per MWh (ACIL Tasman, 2009). Loy Yang B is a third cleaner SCPC in the Latrobe Valley and is also owned by GDF Suez, so effects of an agreement on this plant will also be incorporated for GDF Suez profits. Loy Yang B power plant is not a mine-mouthed operation, instead fueled by the Loy Yang Mine owned by AGL energy running higher fuel costs as a result (GDF Suez, 2016b). The expected operating life of the plants is set for 2031 for Hazelwood and 2032 for Yallourn (Energy Australia, 2016; GDF Suez, 2016a) which is used for calculating NPVs independent of an operating license extension (see CCS in section 4.5).

4.2 Data

The AEMO has produced reports via government agencies with detailed profile data on the incumbent plants operating in the NEM including; CO_2 emission factors, fuel costs, variable operating and maintenance (VOM), fixed operating and maintenance (FOM), expected cost changes with Carbon Capture and Storage (ACIL Tasman, 2009; ACIL Allen, 2014). Fuel costs are converted from \$/GWh to \$/MWh based on thermal efficiency and an average capacity factor of 70% *(ibid).* These VOM and FOM costs are expected to remain flat for their operating life, with low risk due to the vertical integration and the power plants fully owned (Jotzo & Mazouz, 2015). Wholesale electricity prices were projected out from data in Caldecott *et al.* (2015) which uses linear regression analysis of average wholesale prices in NEM territories with SCPCs over

[11] Hazelwood is owned by GDF Suez and Yallourn by Energy Australia.
[12] The lignite mine sits alongside the power plant, allowing for low transportation costs of fuel.
[13] Referred to as electricity sold in the market.

the period 1998-2015. These increases are assumed to continue at the resultant rate of $.79 per year, with a baseline assumption of $41.015 per MWh for 2016.

Jotzo and Mazouz (2015) report on average capacity factors dropping to 70% for 2014 due to the recent falling electricity demand coupled with exogenous shocks such as mine fires and flooding disruptions to operations. Furthermore, demand is expected to flatten out over the following decades (Brinsmead *et al.*, 2014; AEMO, 2016). This capacity factor is taken as the BAU setting in our study. In the event of a plant exit with Jotzo and Mazouz (2015)'s mechanism, they assume a 10% increase in output for the remaining LV brown coal plants, resulting in capacity factors of 77% for Hazelwood or Yallourn in the agreement scenario. The authors expect black coal to make-up the remainder lost generation with an emission factor of 0.91t CO_2-e/MWh, supported by a recent emission factors update (ACIL Allen, 2016). Baseload power plants are expected to operate 24 hours a day due to low MCs and high ramp-down and ramp-up costs[14] (Ward, 2015), which is used to calculation expected dispatched generation at the 70% capacity factor. This generation figure multiplied by their emission intensity provides their expected annual emissions. A tax rate of 21% is taken along with the discount rate used of 9% as is used as in Caldecott *et al.* (2015)'s payments for closure estimates for all SCPCs in the NEM. They expect their discount rate to be conservative to provide the regulator with extra assurance on the maximum amount needed to be paid to close these plants. Due to risk of future emission controls by subsequent governments this rate could be expected to be higher.

4.3 Decommissioning and Rehabilitation Costs

There is much uncertainty surround the end-of-life clean-up costs for the plants and their mines. Specifically, this refers to the decommissioning and rehabilitation costs of both the plant and the mine sites. For an agreement to be successful, it must incorporate these costs into the offer made to the other plant. While there is much uncertainty in public knowledge about these costs, the plants themselves are expected to have relatively accurate estimates of their own and each other's costs due to their similar profiles. Current rehabilitation bonds in place by the owners are expected to fall well short at the scheduled closure date, as plants try to downplay their true costs in the public eye (Slezak & Farrer, 2016). This provides an incentive for the plant to accept an offer. A number of Environment Victoria (2014) reported expected mine rehabilitation costs as a

[14] Costs associated with shutting down and starting up operations respectively

high-case scenario of \$200m. Recently, AECOM (2015) suggested even more conservative figures with a 'conservative but realistic' estimate that expects with an 80% probability that the actual cost is less than the nominated amount (P80). Our study will take this estimate to help to assure the regulator that there is low risk of an agreement failing due to underestimating these costs. These mine costs are in addition to expected plant decommissioning and rehabilitation costs taken from AEMO (2014) with specific estimates for Hazelwood and Yallourn of \$80,000 per MWh capacity.

4.4 Emission Performance Standards

The government previously proposed new-entrant coal generation meet a 'best practice emission standard' of 0.86t CO_2-e/MWh (Department of Resources, Energy and Tourism, 2010). Concerns over the stringency level effect on CCS technology development and forcing plants to commit to unproven technologies caused it to be shelved (Talberg & Nielson, 2011). Our study proposes the policy is only implemented on two of the worst power plants to improve their emission performance marginally with cleaner plants. Yallourn and Hazelwood have emission intensities of 1.42 and 1.53t CO_2-e/MWh respectively. The other two major LV SCPC brown coal power plants, Loy Yang A and Loy Yang B, are considerably more efficient emitting 1.22 and 1.24t CO_2-e/MWh respectively (ACIL Tasman, 2009) attributed to them being 10-20 years younger. Our study has selected the 'low stringency' performance standard to be met as 1.2t CO_2-e/MWh – a reduction of 0.33t CO_2-e/MWh for Hazelwood and 0.22t CO_2-e/MWh for Yallourn. This forces them to operate to a level that would move them from the IEA's classification of 'old inefficient subcritical' to 'old efficient'[15] (IEA, 2012). The stringencies are then incrementally increased by 0.1t CO_2-e/MWh for the medium and high scenarios, equating to standards of 1.1 and 1.2t CO_2-e/MWh respectively.

4.5 The Offer

To avoid the emission performance standard being implemented on the plants, the government allows a short pre-determined bargaining period for negotiations between the plants to agree for one to pay the other to exit the market. We also assume the regulator guarantees Hazelwood and Yallourn that they If they agree on an exit, the government guarantees the successor will not be subjected to future rounds of regulated closures and may emit freely (assumed to exclude

[15] Classified as: old inefficient ≥ 1.34t CO_2-e/MWh, and old efficient between 1.12-1.34t CO_2-e/MWh.

expansions) to encourage an agreement. They are not immune to future first-best industry-wide policy. This avoids issues raised in Carraro & Leveque (2013) of shirking on the VA as the plant is retiring from the market and is no longer a participant. It also benefits the regulator by reducing their monitoring and compliance costs in the case of agreement. However, this will only be accepted by the government if the expected overall emissions are lower from an agreement compared to expected emissions from disagreement and facing the regulation (Schmelzer, 1999).

The offer made by a plant will be affected by the expectation that the other will be able to survive financially with the new regulation. One plant will not offer a payment for exit to another if they knew that when faced with the actual regulation they would make a decision to exit anyway. An offer made is expected to be less than what the offeror would receive in the case of the other plant leaving and the offeror's expected NPV of future profits. Likewise, a successful offer is expected to be more than the amount received by the offeree under disagreement, otherwise they would prefer to face the regulation. Additionally, the offer also must include the upfront cost of the decommissioning and rehabilitation for the exiting plant as with the hybrid mechanism of Jotzo and Mazouz (2015). This can be represented with plant *i,j* as:

$$M_i\,(\mathrm{e})^{OR/CC} + D_i \leq X_i \leq M_j\,(i \text{ exit}) \tag{3}$$

This cost D_i is also deducted from future profits at the end of the plant *i*'s life, which is included in $M_i\,(\mathrm{e})^{OR/CC}$. This is discounted at the rate of 9%, so it is much less than the upfront cost for plant *j*. This condition can also be represented in terms of equation (2), where the share of the surplus for the exiting plant *i* incorporated into X_i, must be greater or equal than their decommissioning and rehabilitation costs *Di*:

$$\tfrac{1}{2}\,(M_j\,(i \text{ exit}) - d_i + d_j) \geq D_i \tag{4}$$

Nelson *et al.* (2015, p.39) states that generators should theoretically be indifferent between operating and closing if they receive an income stream equal to their expected operating income, or it may even be preferred as it removes operational risk such as outages.

4.6 Disagreement Points

Abatement options to meet the regulation threatened by the government and which will determine the NPVs of expected profits under a disagreement scenario consist of – reduction of their output, or, installation of Carbon Capture and Storage Technology (CCS). The cheaper alternative or combination of the two will act as the disagreement point.

Output reduction or mothballing of capacity, refers to the plants acting as if they were cleaner by limiting their emissions from their base level (BAU) of output to what they would be if they were under the set emission standard, shown in equation (5).

$$\frac{BAU\ output\ x\ set\ emission\ standard}{actual\ emission\ intensity} = Allowed\ Output \qquad (5)$$

This results in further mothballing of plant capacity as the capacity factors are reduced from the BAU 70% level. The cost to the plants is the foregone profit from the lost generation in meeting the emissions standard.

CCS is still an emerging technology which captures carbon emissions before they are released into the atmosphere and sequestering it in a safe storage sites. It is important to include the viability of CCS in our study, as the government has recently stated that coal will remain an integral part of Australia's energy mix for the foreseeable future (Murphy, 2017). The first commercial grade post-combustion CCS facility operating since October 2014, is installed on a 139MW unit of SaskPower's Boundary Dam Facility in Saskatchewan, Canada (SaskPower, 2016). It shares similar characteristics as a 35+ year old highly-emitting, brown coal-fueled power plant, making it an ideal candidate to model for the plants in this study.

The modelling of Carbon Capture and Storage of CO_2 on the world's first commercial grade CCS facility requires numerous assumptions. Viability of installation on ageing generators requires refurbishment, which constitutes 30% of SaskPower's A\$1.249bn cost. SaskPower announced that the project could be completed at a 20-30% discount due to the learning efficiencies (MIT, 2016). We conservatively estimate a 15% reduction in costs with technology improving, but due to the larger sized units in this study. According to government reports, we allow for a 15 year operating license extension for the generators and their mines with the installation of CCS (ACIL Allen, 2013). A 10% parasitic load[16] is estimated as an expected improvement from Boundary Dam (MIT, 2016). Installation of CCS is limited to the whole capacity of a generating unit. SaskPower installed their CCS on a refurbished unit of 139MW capacity, whereas Hazelwood

[16] The foregone dispatchable energy due to its use in operating the CCS facility.

consists of 8 x 200MW units, and Yallourn 350MW and 375MW capacity units. As a result, the installation cost is estimated by extrapolating out discounted costs to these sized units. VOM and FOM costs are expected to increase for CCS installed on the entire plant capacity by $6 MWh and $5.13/MWh (ACIL Allen, 2014). Although these costs change their place in the merit order, the magnitude of the change in SRMC due to increased VOM which controls operating decisions (Ward, 2015) is not expected to remove them from the merit order to meet demand (Brinsmead *et al.*, 2014, p 28). CO_2 storage in this study assumes use of the Australian and Victorian government funded 'CarbonNet Project, a feasibility study on a commercial grade piping system from the LV to the Gippsland Offshore Basin for safe storage (VIC Government, 2016). The CO_2 capture rate from Boundary Dam has averaged 90% and is also assumed in this study (MIT, 2016).

4.7 Regulatory Uncertainty

An important aspect of the cooperative bargaining game is that the threat of regulation needs to be credible. Recent uncertainty in the political landscape of Australia has affected credibility of environmental policies (Riesz & Noone, 2013; Nelson *et al.*, 2015; Senate Committee, 2017). A credible threat increases the likelihood of the bargaining game running effectively, and reaching an agreement which is the optimal outcome for the government. If the threat is considered weak by the polluters, they will prefer to face the regulation. Glachant (2007) states that credible threats ensure compliance, otherwise polluters may use a VA as a strategy to delay legislation with no intension of abating. This is not seen as a risk for our study as previously stated that if a VA is reached, a plant will permanently retire from the market by a set date. It may also be assumed that the plants are subjected to harsh monetary penalties or loss of mining licenses to help alleviate credibility concerns in the event of non-compliance with an emission standard. Counteracting this is the high degree of lobbying power of the coal industry demonstrated with the recent announcement of the government's backing for 'clean coal' or CCS (Edis, 2017), which could influence and weaken the regulation's stringency or penalties set (Caldecott *et al.*, 2015, p 28). Uncertainty would be further limited if bipartisan support for the policy was obtained (Wood & Mullerworth, 2015), as changes in government may see the policy repealed or replaced. A repeal should be considered unlikely however, as the centre-left opposition have supported even more stringent policies such as an emission intensity schemes (Australian Labour Party, 2016).

This study will introduce uncertainty by way of probabilities to represent anticipations (Nash, 1950) of the emission standard being effectively implemented. This in turn will impact upon the expected profit calculated in the different scenarios. We introduce probability p that the policy will be introduced or remain in place. This can also be thought of as the amount of time that the policy is expected to be introduced on future profits, and *1-p* serves as the expectation that the policy will not be implemented and profits will correspond to the base case scenario. A lower p increases the value of the threat point[17], and increases the likelihood of the bargaining failing.

4.8 The Nash Bargaining Game

Utility is measured by each dollar the firm receives under the cases. Using the stated data and assumptions, the firms will calculate the Net Present Values of their expected profits for the Agreement scenarios and Disagreement scenarios under the different emission standards. Each plant then offers the other a payment to exit the market.

Variables:

i,j	Plant (H,Y)
M_j (condition)	NPV of income for plant i, dependent on: emission constraint, plant exit
D_j	Decommissioning and rehabilitation cost of plant and mine of i
X_i	Total offer paid to plant i
U_i	Agreement utility of plant i
d_i^{CCS}	Disagreement utility for plant i from CCS
d_i^{OR}	Disagreement utility for plant i from output reduction
e	Emission performance standard (constraint)
p	Probability of emission constraint being imposed

First we will calculate the values of the agreement payoffs and disagreement payoffs:

Agreement Pairs (U_H, U_Y):

H offering Y to exit:

$$[M_H(\text{Y exit}) - X_Y, X_Y] \text{ s.t. } (M_Y^{OR/CC}(\text{e}) + D_Y \leq X_Y \leq M_H(\text{Y exit})) \quad (6)$$

[17] This is also known as the disagreement point or disagreement outcome.

Y offering H to exit:

$[M_Y(\text{H exit}) - X_H, X_H]$ s.t. $(M_H^{OR/CC}(\text{e}) + D_Y \leq X_H \leq M_Y(\text{H exit}))$ (7)

Disagreement pairs (d_H,d_Y):

i) Carbon Capture (d_H^{CC}, d_Y^{CC}):

$[p\,(M_H^{CC}(\text{e})) + (1-p)\,M_H(\text{no constraint}),\ p\,(M_Y^{CC}(\text{e})) + (1-p)\,M_Y(\text{no constraint})]$ (8)

ii) Output Reduction (d_H^{OR}, d_Y^{OR})

$[p\,(M_H^{OR}(\text{e})) + (1-p)\,M_H(\text{no constraint}),\ p\,(M_Y^{OR}(\text{e})) + (1-p)\,M_Y(\text{no constraint})]$ (9)

The disagreement pair that optimises net profit (if the bargaining results in disagreement) is selected to be used in the bargaining game.

4.8.1 No uncertainty case

We let $p=1$ for 100% credibility of the regulatory threat.

I. *For scenario where Hazelwood offers Yallourn payment to exit:*

With symmetric information, we substitute the agreement and chosen disagreement values into equations in (2):

$U_H^N = d_H + ½\,(M_H(\text{Y exit}) - d_H + d_Y)$, $\boldsymbol{X_Y} = U_Y^N = d_Y^N + ½\,(M_H(\text{Y exit}) - d_H + d_Y)$ (10)

If condition in expression (3) is met, then an agreement is reached between the plants and an exit is achieved.

II. *Repeat (I.) for alternative of Yallourn offering Hazelwood payment to exit*

4.8.2 Uncertainty case

We now let p exist s.t. $0 \leq p \leq 1$, representing regulatory credibility for plant owners. We examine this on the emission standards that induce an exit, which is optimal for a regulator. We solve for the point where the credibility of the threat *(p)* weakens to the point where the offeree is indifferent between remaining in, or leaving the market, represented by the offer from expression (3):

$$X_i = M_i^{CC/OR}(\text{e}) + D_i \quad (11)$$

We then substitute (11), and the agreement and disagreement pairs from the optimal stringency for an exit, into the Nash Product from equation (1):

$f(X,p)$ = [M_j (i exit) – (D_i + $M_i^{CC/OR}$ (e)) – (p $M_j^{CC/OR}$(e) + (1 – p) M_j (no constraint))] [(D_i + $M_i^{CC/OR}$ (e)) – (p $M_i^{CC/OR}$(e) + (1 – p) M_i (no constraint))] (12)

We optimize and solve for *p,* using the 2nd derivative to test for a local minimum. If this is met, the value for *p* will be the level of uncertainty at which the agreement will fail.

5. Results and Discussion

Table 5.1 – Base Case Scenario Outcomes

Base Case (BAU)		Hazelwood	Yallourn	Totals
	Capacity factor	**70%**	**70%**	
	Generation sent-out (MWh)	9,811,200	9,075,360	18,886,560
	Emissions (kt)	15,011	12,887	27,898
	Life Income (NPV)	$ 1,082,030,561	$ 1,122,468,539	$ 2,204,499,100

Examining the BAU setting with an assumed average capacity factor of 70%, resulting generation leads to base CO_2 emissions of 15,011kt for Hazelwood and 12,887kt for Yallourn, or 27,898kt of CO_2 emissions in total. This combined amount is the important reference level for the government. For cooperative bargaining under an emissions threat to be an effective tool, any outcome from the bargaining game needs to lead to a material lowering of emissions below this reference level (Schmelzer, 1999).

5.1 Disagreement Outcomes

We first determine the baseline level of emissions set under the emission performance standards, and the corresponding generation allowed for the plants based on their emission intensities (Table 5.2).

Table 5.2 – Emissions and Generation allowed under the EPS

	Emission Allowed (kt)			Generation Allowed (MWh)			Capacity Factors	
E Stds	**Hazelwoo**	**Yallourn**	**Total**	**Hazelwood**	**Yallourn**	**Total**	**Hazelwood**	**Yallourn**
1	9,811	9,075	18,887	6,412,549	6,391,099	12,803,648	46%	49%
1.1	10,792	9,983	20,775	7,053,804	7,030,208	14,084,012	50%	54%
1.2	11,773	10,890	22,664	7,695,059	7,669,318	15,364,377	55%	59%

As Hazelwood generates emissions at a rate of 1.53t CO_2-e/MWh, it consumes its allowed emissions (eqn. (5)) at a faster rate than Yallourn at 1.42t CO_2-e/MWh. The constraint is tougher against a dirtier plant than a cleaner one, reducing the larger capacity advantage that Hazelwood held over Yallourn. This effect increases as the emission standards stringency increases. For perspective, under the BAU scenario Yallourn generates 735,840 MWh p.a. less than Hazelwood, whereas under a 1.2t CO2-e standard, this gap dramatically reduces to 26,000MWh less than Hazelwood.

5.1.1 Output Reduction

We now determine the values for the disagreement pairs (d_i,d_j) that result from plant owners choosing to mothball capacity to the levels from Table 5.2:

Table 5.3 – Output reduction outcomes

With Output Reduction		Hazelwood	Yallourn	Make-up Generation*	Totals	Emissions Saving (%)
1.2 t-e CO2/MWh	Life Income (NPV)	$ 491,996,417	$ 665,309,715		$ 1,157,306,132	
	Cost NPV (lost income)	$ 735,368,813	$ 622,591,656		$ 1,357,960,470	
	Emissions p.a. (kt)	11,773	10,890	3,870	**26,534**	
	E saved p.a. (kt)	3,238	1,997		**1,364**	4.9%
1.1 t-e CO2/MWh	Life Income (NPV)	$ 311,819,738	$ 480,834,102		$ 792,653,839	
	Cost NPV (lost income)	$ 1,159,899,441	$ 968,153,473		$ 2,128,052,914	
	Emissions p.a. (kt)	10792	9983	5,035	**25,811**	
	E saved p.a. (kt)	4,219	2,904		**2,088**	7.5%
1 t-e CO2/MWh	Life Income (NPV)	$ 131,001,918	$ 295,611,534		$ 426,613,452	
	Cost NPV (lost income)	$ 1,432,159,917	$ 1,247,906,799		$ 2,680,066,716	
	Emissions p.a. (kt)	9,811	9,075	6,200	**25,087**	
	E saved p.a. (kt)	5,200	3,812		**2,811**	10.1%

As stringency increases and capacity is mothballed, the plants earn less income as their generation dispatched is constricted. Each still earns positive net profit under all constraint stringencies, representing the ability of these plants to be able to 'sweat out'[18] operations and still remain profitable (Nelson *et al.*, 2015). Emissions are expected to be less in practice so that the plants don't run too close to the baseline and risk penalties. This would further reduce threat point values and increase the likelihood of an agreement. The reduced output is replaced by predominantly lower-emitting black coal plants (0.91t CO_2-e/MWh), and an increase in the capacity factor of 10% from the remaining three LV brown coal plants (Jotzo & Mazouz, 2015; ACIL Allen, 2016). If the plants are faced with the weaker standard of 1.2t CO_2 emitted per MWh, total emissions are 26,534kt of CO_2 p.a., which represents a saving of 1,364kt of CO_2 or 4.9% annually over the base case. With the medium stringency of 1.1t CO_2 emitted per MWh, corresponding emissions are 25,811kt of CO_2 p.a, representing a saving of 2,088kt of CO_2 or 7.5% annually. The most stringent case of 1.0t CO_2 emitted per MWh, emissions generated are 25,087kt of CO_2 equating to savings of 2,811kt of CO_2 over the base case. These reductions are not substantial, owing to the fact that Hazelwood and Yallourn still retain relatively high capacity factors (Table 5.2) in all the modelled emission standards. For the regulator to achieve

[18] The owners temporarily shut down some of the generating capacity in periods of low demand.

higher emission reductions under output reduction, more stringent standards must be taken which would be unlikely to be implemented due to the high influence of the coal industry in the Australian political scene (Edis, 2017). A weaker emission standard of 1.2 tCO_2-e/MWh is the most likely to eventuate, considering it also brings the plants in line with similar brown coal generators[19] in the Latrobe Valley.

Still, the primary goal for the regulator is to achieve a plant exit. Regulated mothballing, while stronger than voluntary mothballing, provides a weaker signal to new renewable generating capacity to enter the market in comparison to a plant exit where capacity is permanently removed (Riesz & Noone, 2013).

5.1.2 Carbon Capture and Storage

SaskPower's investment cost for the CCS project was A$1.249bn for a 139MW capacity facility which included a refurbishment of the generator (SaskPower, 2012). The discounted cost is extrapolated out for the different sizes of Hazelwood and Yallourn's generating units in increments shown in Table 5.4, adjusting for the exchange rate. We also check if there are any optimal strategy combinations of CCS installation and mothballing of capacity.

Table 5.4 - CCS investment cost (modelled from SaskPower's Boundary Dam facility)

CCS INVESTMENT COST			
Hazelwood		**Yallourn**	
Unit size (MW)	E(cost)	Unit size (MW)	E(cost)
200	$ 1,527,850,211.80	350	$ 2,673,737,870.65
400	$ 3,055,700,423.60	700	$ 5,347,475,741.29
600	$ 4,583,550,635.40		
800	$ 6,111,400,847.19		

Ex rate: 1 AUD = 0.9925 CAD (23rd August 2017)

[19] Loy Yang A and Loy Yang B have emission factors of 1.22 and 1.24 t CO_2 per MWh sent-out respectively (ACIL Tasman, 2009).

Table 5.5 - CCS Outcomes

CCS Installed (H/Y)		Hazelwood	Yallourn	Make-up Generation*	Totals	Emissions Saving (%)
200 MW/350MW	Life Income (NPV)	$ 402,332,267	$ (564,465,752)		$ (162,133,485)	
	Cost NPV	$ 825,032,963	$ 1,852,367,124	N/A	$ 2,677,400,086	
	Emissions p.a. (kt)	13,322	10,144		**23,467**	
	E saved p.a. (kt)	1,689	2,743		**4,432**	15.9%
400 MW/350MW	Life Income (NPV)	$ (833,307,733)	$ (564,465,752)		$ (1,397,773,485)	
	Cost NPV	$ 2,060,672,963	$ 1,852,367,124	N/A	$ 3,913,040,087	
	Emissions p.a. (kt)	11,634	10,144		**21,778**	
	E saved p.a. (kt)	3,378	2,743		**6,120**	21.9%
600MW/700MW	Life Income (NPV)	$ (1,950,418,808)	$ (2,723,269,925)		$ (4,673,688,733)	
	Cost NPV	$ 3,177,784,038	$ 4,011,171,297	N/A	$ 7,188,955,334	
	Emissions p.a. (kt)	9,945	7,401		**17,346**	
	E saved p.a. (kt)	5,066	5,486		**10,552**	37.8%

CCS achieves much larger emission reductions from the BAU scenario than reducing output manages. The units with CCS installed are expected to captures 90% of emissions (SaskPower, 2016) which delivers much cleaner electricity to the market. Furthermore, no reduction in capacity means that there is no covering brown or black generation required which keeps emissions relatively high. Despite this, these achievements are overshadowed by the technology remaining prohibitively expensive for the generators. All of Yallourn's CCS combinations earn negative net income, despite the extension in its operating life. Hazelwood earns positive net income when installing on the 200MW unit with $402.3bn, but any additional rollouts also result in negative net income over its life. Yallourn is less flexible with the rollout of CCS due to its generating units of 350MW being almost double the size of Hazelwood's. Still, if the government was to threaten a 1.2t CO_2-e/MWh EPS, installing 200MW of CCS for Hazelwood does not meet the baseline emissions of 11,773kt, whereas mothballing to reach the baseline level earns net income of $492 and is the dominant strategy. Based on the first commercial CCS facility in operation, the results show that the technology is not cost effective enough for the plants to consider investing at this stage. Boundary Dam's decision to invest may be explained by their operations being supported by a secondary income stream from the on-selling of their captured CO_2 for enhanced oil recovery (MIT, 2016). We have kept the same discount rate for CCS income as for the other income streams in our analysis. It could also be argued that the income from the CCS technology should be discounted at a higher rate due to the option value they retain of waiting to invest at a later date once the technology has improved, further compounding the weakness of CCS.

5.1.3 Disagreement Point Selection

The dominant strategy for Hazelwood and Yallourn under all emission standards is mothballing of capacity and its values will be used for the disagreement points as shown in Table 5.6.

Table 5.6 - Dominant strategies and values for disagreement points

Emission Standard (tCO_2-e/MWh sent-out)	**Hazelwood**	**Yallourn**
1.2	Mothballing **$492m**	Mothballing **$665.3m**
1.1	Mothballing **$311.8m**	Mothballing **480.8m**
1.0	Mothballing **$131m**	Mothballing **$295.6m**

All three disagreement values are higher for Yallourn than Hazelwood. This stems from a combination of Yallourn's lower emission intensity and higher profit margin, despite it being offset partially by Hazelwood's larger capacity. This acts as a negotiating tool for Yallourn to receive a higher offer from Hazelwood than vice versa. Technological and cost efficiencies will continually improve CCS in the coming years, increasing its viability for the disagreement outcomes. This is demonstrated with significant improvements in parasite loads shown in previous studies (Kolstad & Young, 2010) compared with that of Boundary Dam. Improved profitability of CCS will increase the disagreement point income as CCS is substituted for output reduction. This directly translates to reducing the likelihood of an agreement, as the available surplus to split shrinks, as M_i^{CC} (e) increases in the offer condition of expression (3).

5.2 Agreement Outcomes

For an agreement to be reached, the offer made to the retiring plant must be less than the payoff to the remaining plant from remaining in the market or from expression (3); $X_i \leq M_j$ (i exit). Table 5.7 shows the expected payoffs if the other was to exit (excluding payment X_i).

Table 5.7 - Agreement Point Outcomes

Agreements		Hazelwood	Yallourn	Make-up Generation*	Totals	Emissions Saving (%)
Yallourn Exit	Capacity factor	**77%**	EXIT			
	Generation sent-out (MWh)	10,792,320	-	8,094,240	18,886,560	
	Emissions (kt)	16,512	-	8,031	**24,543**	
	E saved p.a. (kt)	(1,501)	12,887	(8,031)	**3,355**	12.0%
	Life Income (NPV)	**$ 1,521,029,671**			$ 1,521,029,671	
Hazelwood Exit	Capacity factor	EXIT	**77%**			
	Generation sent-out (MWh)	-	9,982,896	8,903,664	18,886,560	
	Emissions (kt)	-	14,176	8,767	**22,943**	
	E saved p.a. (kt)	15,011	(1,289)	(8,767)	**4,955**	17.8%
	Life Income (NPV)		**$ 1,425,942,266**		$ 1,425,942,266	

A Yallourn exit is expected to earn Hazelwood net income of $1.521bn over its scheduled life, whereas a Hazelwood exit is expected to net Yallourn $1.426bn – a difference of $95m. This does not take into account expected wholesale price rises in the NEM from the reduced overcapacity. Hazelwood is benefited by the uplift in capacity of its smaller plant Loy Yang B, which earns owners GDF Suez an additional $111.2m. Without the Loy Yang B effect, Yallourn would have the higher net income due to their cleaner production capability and higher profit margins. As a result, Hazelwood will be able to provide a larger surplus than Yallourn after accounting for the threat point values. From an emission perspective, the regulator prefers a Hazelwood exit which achieves an additional 5.8% or 1600kt of CO_2 abatement annually from the base case, explained by Hazelwood's larger capacity and emission intensity.

5.3 Determining the Nash Bargaining Solution:

Having calculated the expected utilities or incomes under agreement and disagreement scenarios, we now calculate outcome of the bargaining game to find the Nash Bargaining Solution (u_H^N, u_Y^N) under each of the emission stringencies, to determine if an agreement can be reached and the expected payment required.

5.3.1 No Regulatory Uncertainty

Total decommissioning and rehabilitation costs are set to: D_H =\$433m and D_Y = \$317.4m, and substituting into equations in (10):

1) <u>Government Threatens 1.2t CO_2-e per MWh:</u>

Scenario: Hazelwood offers Yallourn 'X' payment (million $):

$U_H^N = 492 + ½ (1521 – (492 + 665.3))$ and $U_Y^N = 665.3 + ½ (1521 – (492 + 665.3))$

$U_H^N = 673.85$ and $U_Y^N = 847.15 = \boldsymbol{X_Y}$

Condition not met: $X_Y = \$847.15\text{m} \ngeq 665.3 + 317.4$

Scenario: Yallourn offers Hazelwood 'X' payment (million $):

$U_H^N = 492 + ½ (1425.9 – (492 + 665.3))$ and $U_Y^N = 665.3 + ½ (1425.9 – (492 + 665.3))$

$U_H^N = 626.3 = \boldsymbol{X_H}$ and $U_Y^N = 799.6\text{m}$

Condition not met: $X_H = 626.3 \ngeq 492 + 433$

Hazelwood's offer to Yallourn is greater than Yallourn's to Hazelwood and is the dominant offer. However the offer does not meet the condition: $X_Y \geq M_Y^{OR/CC}(e) + D_Y$. As a result Yallourn will reject Hazelwood's offer and no agreement is reached. Yallourn's offer to Hazelwood is also rejected for failing the condition. The upfront decommissioning and rehabilitation costs are expected to prevent an agreement.

2) Government Threatens 1.1t CO_2-e per MWh:

Scenario: Hazelwood offers Yallourn 'X' payment (million $):

$U_H^N = 311.8 + ½ (1521 – (311.8 + 480.8))$ and $U_Y^N = 480.8 + ½ (1521 – (311.8 + 480.8))$

$U_H^N = 676$ and $U_Y^N = 845 = \boldsymbol{X_Y}$

Condition met: $X_Y = 845 \geq 480.8 + 317.4$

Scenario: Yallourn offers Hazelwood 'X' payment (million $):

$U_H^N = 311.8 + ½ (1425.9 – (311.8 + 480.8))$ and $U_Y^N = 480.8 + ½ (1425.9 – (311.8 + 480.8))$

$U_H^N = 628.45 = \boldsymbol{X_H}$ and $U_Y^N = 797.45$

Condition not met: $X_H = 628.45 \ngeq 311.8 + 433$

Again Hazelwood's offer is dominant to Yallourn's due to its larger threat points, but this time the split surplus to provide Yallourn is expected to exceed D_Y by \$46.8m. This is not the case for

Hazelwood who despite having a lower disagreement point than Yallourn, has a much larger decommissioning and rehabilitation cost. Therefore this is the least stringent emission standard that results in a plant exit for the regulator. Hazelwood's utility increases by \$2.15m as stringency increased from 1.2 to 1.1t CO_2-e per MWh, in both scenarios, whereas Yallourn's utility decreased by \$2.15m in the same settings.

3) Government Threatens 1.0t CO_2-e per MWh:

Scenario: Hazelwood offers Yallourn 'X' payment (million \$):

$U_H^N = 131 + ½ (1521 – (131 + 295.6))$ and $U_Y^N = 295.6 + ½ (1521 – (131 + 295.6))$

$U_H^N = 678.2$ and $U_Y^N = 842.8 = \mathbf{X_Y}$

Condition met: $X_Y = 842.8 \geq 295.6 + 317.4$

Scenario: Yallourn offers Hazelwood 'X' payment (million \$):

$U_H^N = 131 + ½ (1425.9 – (131 + 295.6))$ and $U_Y^N = 295.6 + ½ (1425.9 – (131 + 295.6))$

$U_H^N = 630.65 = \boldsymbol{X_H}$ and $U_Y^N = 795.25$

Condition met: $X_H = 630.65 \geq 131 + 433$

Clearly, under the strictest emission standard the surplus again grows which comfortably covers the cost D_i for both Hazelwood and Yallourn. Utility has again increased for Hazelwood by \$2.2m and decreased for Yallourn by the same amount. The slight difference of \$0.05m from the change in utility for each from 1.2t to 1.1t emission standard is attributed to rounding. Therefore, utility increases at a constant rate for Hazelwood and decreases at a constant rate for Yallourn as the stringency of the emission standards is incrementally increased. A higher stringency equates to a lower overall threat point value and a larger surplus, leading to a lower minimum acceptable payment for Yallourn. The surplus increases at a greater rate than the reduction in the minimum payment for Yallourn, as it does not take into account the Hazelwood's portion of the surplus.

Taking the case of no uncertainty and the assumption of P80 end-of-life costs, the optimal emission standard for the regulator to achieve a plant retirement is 1.1t CO_2-e/MWh. The feasibility of the policy increases if a less stringent policy also achieves their objectives. As previously discussed, this is due to the likelihood of a weaker policy being politically acceptable due to the lobbying power of the coal industry, as well as reducing the risk of a joint exit and price rises from supply shortages in Victoria (AEMO, 2014). The failure of the 1.2t EPS could be prevented by the government offering relatively minimal funding of $135.6m to cover the shortfall. Moreover, this is not expected exacerbate barriers to exit (Riesz & Noone, 2013, p 17). There is also a possibility that the 1.2t EPS could succeed due to the owners willing to accept less than the calculated offer, funding part of the decommissioning and rehabilitation costs themselves.

Although an agreement is theoretically achieved, the large offer to be paid may lead to concern that the plant will be unable to pay such a large amount upfront. The expected offers equate to almost 5 years of Hazelwood and Yallourn profit following the exit of the other plant. One way to bypass this issue could be by the two firms enter into a contract specifying a payment schedule for Hazelwood as they earn income, suggested in Nelson *et al.* (2015; p.39). However, there is the possibility that both plants may choose to exit the market due to unwillingness or inability to make the large payment.

As the highest emitting plant and oldest in the NEM, Hazelwood may instead prefer to exit the market, unwilling or unable to offer $845m to Yallourn. Instead, an acceptable offer to Hazelwood from Yallourn is expected to be $217m less and therefore more manageable. Furthermore, a Hazelwood exit is preferable to the regulator, achieving an additional 5.8% or 1600kt of CO_2 abatement annually. However if Yallourn suspects Hazelwood's willingness to exit, they may reduce their offer which may risk a breakdown in negotiations and the agreement. The period allowed to reach an agreement must allow for healthy and efficient negotiation, but be relatively short to avoid delaying regulation and undermining of threat credibility (Nelson *et al.*, 2015).

5.3.2 Uncertainty of Threat Point Credibility

So far, we have dealt with plant expectations that the plant's threat will be introduced with 100% certainty. Recent volatility in the Australian political landscape may cause the plants to lower their expectations on the credibility of the regulatory threat which is now introduced.

We now let $0 \leq p \leq 1$ and take the agreement outcomes from the previous case of no uncertainty to substitute into equation (11).

Agreement from 1.1t CO_2-e per MWh

$$f(X,p) = [(1521 - X) - (311.8p + (1 - p)\ 1082)]\ [(X - (480.8p + (1 - p)\ 1122.5)] \quad (13)$$

From equation (11), the minimum expected acceptable payoff for Yallourn for an agreement will be $X_Y = 798.2$. Substituting the values into equation (13):

$$f(p) = [(1521 - 798.2) - (311.8p + (1 - p)\ 1082)]\ [798.2 - (480.8p + (1 - p)\ 1122.5)]$$

$$f(p) = (722.8 - 311.8p - 1082 + 1082p)\ (798.2 - 480.8p - 1122.5 + 1122.5p)$$

$$f(p) = (770.2p - 359.2)\ (641.7p - 324.3)$$

$$f(p) = 494237.34p^2 - 480274.5p + 116488.56$$

$$f(p) = 988474.68p - 480274.5$$

let $f'(p) = 0$ and solve for p:

$$p = 0.4859 = 48.6\%$$

$f''(p) > 0$ and therefore is a local minimum

Under a 1.1 tCO_2-e per MWh EPS, the point where $p = 0.4859$ is where Hazelwood's offer to Yallourn exactly equals Yallourn's minimum acceptable payment of \$798.2m covering their disagreement value from mothballing capacity and upfront decommissioning and rehabilitation costs from exiting. If plant owners have an expectation of $\lesssim$ 49% that the policy will have no effect on BAU level income, they are expected to reject the offer. The emission standard of 1.1t of CO_2-e per MWh cannot be expected by the plant owners to have a credibility of $\lesssim$ 49% if the policy is to succeed in achieving a plant exit.

Agreement from 1.0t CO_2-e per MWh

$$f(X,p) = [(1521 - X) - (131\ p + (1 - p)\ 1082.0)]\ [X - (295.6p + (1 - p)\ 1122.5)] \quad (14)$$

From expression (11), the minimum acceptable payoff for Yallourn to form an agreement will be $X_Y = 613$. Substituting into equation (14):

$$f(p) = [(1521 - 613) - (131p + (1 - p)\ 1082)]\ [613 - (295.6p + (1 - p)\ 1122.5)]$$

$$f(p) = (908 - 131p - 1082 + 1082p)\ (613 - 295.6p - 1122.5 + 1122.5p)$$

$$f(p) = (951p - 174)\ (826.9p - 509.5)$$

$$f(p) = 786381.9p^2 - 628415.1p + 88653$$

$$f'(p) = 1572763.8p - 628415.1$$

let $f'(p) = 0$ and solve for p:

$$p = 0.3996 = 40\%$$

$f''(p) > 0$ and therefore is a local minimum

If the stringency is increased to a 1.0t CO_2-e per MWh threat, the expected credibility required for the policy decreases to 40%. A more stringent EPS results in less credibility required to facilitate an agreement as expected, although both stringencies allow a low level of regulatory threat credibility in plant owner expectations. Furthermore, a reasonable person may expect that there is a low likelihood of this regulation being weakened by the more regulatory tough opposition party if they were to come to power. Despite ongoing instability in the direction of emissions policy, this provides the regulator with a considerable buffer to help assure of an agreement and optimal emission reductions over disagreement outcomes.

6. Conclusion

Cooperative bargaining under a credible threat of a 1.1t CO_2-e per MWh emissions standard, theoretically achieves an exit of the highly-emitting Yallourn power plant to reduce overcapacity concerns. This is despite factoring in very conservative estimates of decommissioning and rehabilitation costs. An agreement is optimal for the regulator, resulting in over 60% more emission reductions than when both plants disagree and face the regulation. It translates to estimated cumulative emission savings of almost 47Mt of CO_2 over the next 15 years (ceteris paribus), and reducing the expected gap for meeting Australia's 2030 emissions target with current policy by 4.1% (Energetics, 2016).

Due to cost inefficiencies of CCS, the power plants find that mothballing capacity is more profitable for abating under disagreement. As this technology improves and expected installation costs reduce, the coal plants are expected to change their preference in favour of CCS, increasing the disagreement values and reducing the potential surplus and likelihood of an agreement reached.

A less-stringent, but more politically acceptable target of 1.2t CO_2-e per MWh is expected to fail, primarily due to these end-of-life costs that the plants are unable to account for in their offers. Implementing this standard provides less risk of both plants choosing to exit, pressuring energy security and prices in Victoria (AEMO, 2014). Additional government assistance of $136m to help cover these costs could make it optimal for Yallourn to exit under a 1.2t standard. This equates to the government purchasing reductions at $2.69 per tonne of CO_2 – far cheaper than abatement recently purchased through it's ERF[20] (CER, 2017a).

Introducing regulatory uncertainty into the decision making process for plant owners, resulted in a threshold level of almost 51% of uncertainty where negotiations failed under the threat of a 1.1t EPS. This provides a sizeable buffer to accommodate the lack of confidence in the regulatory threat as may be expected in the current political environment (Nelson *et al.*, 2015).

[20] The fifth ERF auction (April 2017) resulted in an average cost to the government of $11.82 per tonne of CO_2 abated.

7. Further Research

Uncertain elements which can impact the ability for an optimal agreement being reached include changes in expectations of the discount rate, wholesale price rises, cost effectiveness of CCS increasing threat points, and the ability of the generators to fund exit payments. Conservative estimates have been taken in this research to improve the validity of the findings. The impact upon agreement payoffs vs disagreement payoffs could be investigated with a sensitivity analysis. However in determining the surplus, the impact upon agreement values could reasonably be expected to be greater than on the lower disagreement point values. Therefore a reduction in net income from a change in a parameter is expected to reduce the potential surplus available and likelihood of reaching an agreement, and vice versa for an increase.

Decommissioning and rehabilitation costs could be more accurately defined with outcomes from an expected national audit of these costs (Senate Committee, 2017). The level at which these costs need to be incorporated into the offer payment for it to be accepted could be further investigated. Detailed modelling is required on potential price rises including; agreement outcomes altering the merit order,[21] oversupply reductions, inducing an earlier retirement than otherwise would have happened without intervention to another plant (Jotzo & Mazouz, 2015; Nelson *et al.*, 2015), levels of cost pass-through from wholesale to retail prices to ensure electricity remains affordable (Jotzo & Mazouz, 2015). Caldecott *et al.* (2015) assumes a 'conservative' discount rate of 9% for public funding to close SCPCs, suggesting this could be much higher.

Mandating a certain level of CCS could be investigated for the regulator to achieve higher emission savings than mothballing if disagreement eventuates. This would cause the disagreement payoffs to decrease and increase the likelihood of an agreement. However, cost and performance inefficiencies of CCS would likely force electricity prices much higher as the regulator doesn't allow for bargaining to decide on the cheapest abatement method, removing the option value for the generators to implement CCS when it is efficient to do so. Furthermore, it increases the risk of a joint retirement with neither choosing to face the regulation, pressuring supply and prices.

[21] The removal of a baseload generator will affect the marginal cost structure of the merit order.

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Appendix A – Base Case Scenario

Wholesale E(p) ($/MWh)		Fuel Costs ($/GJ)			Fuel Costs ($/MWh)			VOM ($)			FOM ($)			Average costs ($/MWh)			Margins ($)			Electricity sent-out @ 70% capacity (MWh)			NPAT @21%		Emissions (kt) BAU		
FY	E(Pw)	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	Total	H	Y	H	Y	Total
2016	41.02	0.09	0.1	0.4	1.03	1.07	3.79	1	1	1	24.89	24.01	18.26	26.92	26.08	23.05	14.10	14.94	17.96	9811200	9075360	18886560	$ 109,273,363.05	$ 107,094,497.45	15011	12887	27898
2017	41.81	0.09	0.1	0.4	1.03	1.07	3.79	1	1	1	24.89	24.01	18.26	26.92	26.08	23.05	14.89	15.73	18.75	9811200	9075360	18886560	$ 115,396,532.97	$ 112,758,429.62	15011	12887	27898
2018	42.60	0.09	0.11	0.41	1.03	1.18	3.88	1	1	1	24.89	24.01	18.26	26.92	26.18	23.15	15.68	16.41	19.45	9811200	9075360	18886560	$ 121,519,702.89	$ 117,653,543.64	15011	12887	27898
2019	43.39	0.1	0.11	0.41	1.15	1.18	3.88	1	1	1	24.89	24.01	18.26	27.03	26.18	23.15	16.35	17.20	20.24	9811200	9075360	18886560	$ 126,755,048.41	$ 123,317,475.82	15011	12887	27898
2020	44.18	0.1	0.11	0.42	1.15	1.18	3.98	1	1	1	24.89	24.01	18.26	27.03	26.18	23.24	17.14	17.99	20.93	9811200	9075360	18886560	$ 132,878,218.33	$ 128,981,407.99	15011	12887	27898
2021	44.97	0.1	0.11	0.42	1.15	1.18	3.98	1	1	1	24.89	24.01	18.26	27.03	26.18	23.24	17.93	18.78	21.72	9811200	9075360	18886560	$ 139,001,388.25	$ 134,645,340.17	15011	12887	27898
2022	45.76	0.1	0.11	0.42	1.15	1.18	3.98	1	1	1	24.89	24.01	18.26	27.03	26.18	23.24	18.72	19.57	22.51	9811200	9075360	18886560	$ 145,124,558.17	$ 140,309,272.35	15011	12887	27898
2023	46.55	0.1	0.12	0.43	1.15	1.29	4.07	1	1	1	24.89	24.01	18.26	27.03	26.29	23.34	19.51	20.25	23.21	9811200	9075360	18886560	$ 151,247,728.09	$ 145,204,386.36	15011	12887	27898
2024	47.34	0.11	0.12	0.43	1.26	1.29	4.07	1	1	1	24.89	24.01	18.26	27.15	26.29	23.34	20.19	21.04	24.00	9811200	9075360	18886560	$ 156,483,073.60	$ 150,868,318.54	15011	12887	27898
2025	48.13	0.11	0.12	0.44	1.26	1.29	4.17	1	1	1	24.89	24.01	18.26	27.15	26.29	23.43	20.98	21.83	24.69	9811200	9075360	18886560	$ 162,606,243.52	$ 156,532,250.72	15011	12887	27898
2026	48.92	0.11	0.12	0.44	1.26	1.29	4.17	1	1	1	24.89	24.01	18.26	27.15	26.29	23.43	21.77	22.62	25.48	9811200	9075360	18886560	$ 168,729,413.44	$ 162,196,182.89	15011	12887	27898
2027	49.71	0.11	0.13	0.45	1.26	1.39	4.26	1	1	1	24.89	24.01	18.26	27.15	26.40	23.53	22.56	23.31	26.18	9811200	9075360	18886560	$ 174,852,583.36	$ 167,091,296.91	15011	12887	27898
2028	50.50	0.12	0.13	0.45	1.37	1.39	4.26	1	1	1	24.89	24.01	18.26	27.26	26.40	23.53	23.23	24.10	26.97	9811200	9075360	18886560	$ 180,087,928.87	$ 172,755,229.09	15011	12887	27898
2029	51.29	0.12	0.13	0.45	1.37	1.39	4.26	1	1	1	24.89	24.01	18.26	27.26	26.40	23.53	24.02	24.89	27.76	9811200	9075360	18886560	$ 186,211,098.79	$ 178,419,161.26	15011	12887	27898
2030	52.08	0.12	0.13	0.46	1.37	1.39	4.36	1	1	1	24.89	24.01	18.26	27.26	26.40	23.62	24.81	25.68	28.45	9811200	9075360	18886560	$ 192,334,268.71	$ 184,083,093.44	15011	12887	27898
2031	52.87	0.12	0.14	0.46	1.37	1.50	4.36	1	1	1	24.89	24.01	18.26	27.26	26.51	23.62	25.60	26.36	29.24	9811200	9075360	18886560	$ (234,542,561.37)	$ 188,978,207.46	15011	12887	27898
2032	53.66		0.14			1.50			1			24.01			26.51			27.15			9075360	9075360	$ -	$ (122,757,860.37)		12887	12887
																	Operational Life Totals			**156,979,200**	**154,281,120**	**311,260,320**	**$1,082,030,560.92**	**$1,122,468,538.99**	**240,178**	**219,079**	**459,257**

Appendix B – Agreement Scenario

					@80% capacity						@80% capacity								
Wholesale E(p) ($/MWh)		Fuel Costs ($/GJ)			Fuel Costs ($/MWh)			VOM ($)			FOM ($) @ 80%			Average costs ($/MWh)			Margins ($)		
FY	E(Pw)	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B
2016	41.015	0.09	0.1	0.4	1.18	1.31	5.24	1	1	1	21.78	21.00	15.98	23.95	23.31	22.22	17.06	17.70	18.80
2017	41.805	0.09	0.1	0.4	1.18	1.31	5.24	1	1	1	21.78	21.00	15.98	23.95	23.31	22.22	17.85	18.49	19.59
2018	42.595	0.09	0.11	0.41	1.18	1.44	5.37	1	1	1	21.78	21.00	15.98	23.95	23.44	22.35	18.64	19.15	20.25
2019	43.385	0.1	0.11	0.41	1.31	1.44	5.37	1	1	1	21.78	21.00	15.98	24.08	23.44	22.35	19.30	19.94	21.04
2020	44.175	0.1	0.11	0.42	1.31	1.44	5.50	1	1	1	21.78	21.00	15.98	24.08	23.44	22.48	20.09	20.73	21.70
2021	44.965	0.1	0.11	0.42	1.31	1.44	5.50	1	1	1	21.78	21.00	15.98	24.08	23.44	22.48	20.88	21.52	22.49
2022	45.755	0.1	0.11	0.42	1.31	1.44	5.50	1	1	1	21.78	21.00	15.98	24.08	23.44	22.48	21.67	22.31	23.28
2023	46.545	0.1	0.12	0.43	1.31	1.57	5.63	1	1	1	21.78	21.00	15.98	24.08	23.58	22.61	22.46	22.97	23.93
2024	47.335	0.11	0.12	0.43	1.44	1.57	5.63	1	1	1	21.78	21.00	15.98	24.22	23.58	22.61	23.12	23.76	24.72
2025	48.125	0.11	0.12	0.44	1.44	1.57	5.76	1	1	1	21.78	21.00	15.98	24.22	23.58	22.74	23.91	24.55	25.38
2026	48.915	0.11	0.12	0.44	1.44	1.57	5.76	1	1	1	21.78	21.00	15.98	24.22	23.58	22.74	24.70	25.34	26.17
2027	49.705	0.11	0.13	0.45	1.44	1.70	5.89	1	1	1	21.78	21.00	15.98	24.22	23.71	22.87	25.49	26.00	26.83
2028	50.495	0.12	0.13	0.45	1.57	1.70	5.89	1	1	1	21.78	21.00	15.98	24.35	23.71	22.87	26.15	26.79	27.62
2029	51.285	0.12	0.13	0.45	1.57	1.70	5.89	1	1	1	21.78	21.00	15.98	24.35	23.71	22.87	26.94	27.58	28.41
2030	52.075	0.12	0.13	0.46	1.57	1.70	6.02	1	1	1	21.78	21.00	15.98	24.35	23.71	23.00	27.73	28.37	29.07
2031	52.865	0.12	0.14	0.46	1.57	1.83	6.02	1	1	1	21.78	21.00	15.98	24.35	23.84	23.00	28.52	29.03	29.86
2032	53.655		0.14			1.83			1			21.00			23.84			29.82	

	Electricity sent-out @ 80% capacity (MWh)			NPAT (Tax @ 21%) of the other exiting			Emissions (kt) from Y Exit			Emissions (kt) from H exit		
FY	H	Y	LY B 10% increase	H	Y	LY B @ 10% for H	H (BAU)	Make-up	Total	Y (BAU)	Make-up	Total
2016	10792320	9982896	735840	$ 145,466,941.98	$ 139,601,425.38	$ 10,926,894.31	15011	9532	24543	12887	10056	22943
2017	10792320	9982896	735840	$ 152,202,428.90	$ 145,831,750.78	$ 11,386,132.05	15011	9532	24543	12887	10056	22943
2018	10792320	9982896	735840	$ 158,937,915.81	$ 151,029,663.22	$ 11,769,270.56	15011	9532	24543	12887	10056	22943
2019	10792320	9982896	735840	$ 164,557,280.61	$ 157,259,988.61	$ 12,228,508.30	15011	9532	24543	12887	10056	22943
2020	10792320	9982896	735840	$ 171,292,767.52	$ 163,490,314.00	$ 12,611,646.81	15011	9532	24543	12887	10056	22943
2021	10792320	9982896	735840	$ 178,028,254.43	$ 169,720,639.40	$ 13,070,884.56	15011	9532	24543	12887	10056	22943
2022	10792320	9982896	735840	$ 184,763,741.34	$ 175,950,964.79	$ 13,530,122.30	15011	9532	24543	12887	10056	22943
2023	10792320	9982896	735840	$ 191,499,228.26	$ 181,148,877.23	$ 13,913,260.81	15011	9532	24543	12887	10056	22943
2024	10792320	9982896	735840	$ 197,118,593.06	$ 187,379,202.62	$ 14,372,498.55	15011	9532	24543	12887	10056	22943
2025	10792320	9982896	735840	$ 203,854,079.97	$ 193,609,528.02	$ 14,755,637.06	15011	9532	24543	12887	10056	22943
2026	10792320	9982896	735840	$ 210,589,566.88	$ 199,839,853.41	$ 15,214,874.81	15011	9532	24543	12887	10056	22943
2027	10792320	9982896	735840	$ 217,325,053.79	$ 205,037,765.85	$ 15,598,013.32	15011	9532	24543	12887	10056	22943
2028	10792320	9982896	735840	$ 222,944,418.59	$ 211,268,091.24	$ 16,057,251.06	15011	9532	24543	12887	10056	22943
2029	10792320	9982896	735840	$ 229,679,905.50	$ 217,498,416.64	$ 16,516,488.81	15011	9532	24543	12887	10056	22943
2030	10792320	9982896	735840	$ 236,415,392.42	$ 223,728,742.03	$ 16,899,627.31	15011	9532	24543	12887	10056	22943
2031	10792320	9982896	735840	$ (189,849,120.67)	$ 228,926,654.47	$ 17,358,865.06	15011	9532	24543	12887	10056	22943
2032		9982896			$ (82,243,020.14)					12887	10056	22943
Operational Life Totals	**172,677,120**	**169,709,232**	**11,773,440**	**$1,409,811,880**	**$1,425,942,266**	**$111,217,790.72**	**240178**	**152510**	**392688**	**219079**	**170953**	**390032**
				NPV (H + LY B - Dh)	**NPV (Y - Dy)**							
				$1,521,029,671	**$1,425,942,266**							
				Y exit	**H exit**							

Appendix C – Disagreement Scenarios: Output Reduction

1. Strict Standard: 1.0 tCO_2-e/MWh

Forecast Electricity prices		Fuel Costs $/GJ			Fuel Costs $/MWh			VOM			FOM			Average costs $/MWh			Margins		
FY	E(Pw)	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B
2016	41.015	0.09	0.1	0.4	0.67	0.76	3.79	1	1	1	38.08	35.34	18.26	39.75	37.09	23.05	1.27	3.92	17.96
2017	41.805	0.09	0.1	0.4	0.67	0.76	3.79	1	1	1	38.08	35.34	18.26	39.75	37.09	23.05	2.06	4.71	18.75
2018	42.595	0.09	0.11	0.41	0.67	0.83	3.88	1	1	1	38.08	35.34	18.26	39.75	37.17	23.15	2.85	5.43	19.45
2019	43.385	0.1	0.11	0.41	0.75	0.83	3.88	1	1	1	38.08	35.34	18.26	39.82	37.17	23.15	3.56	6.22	20.24
2020	44.175	0.1	0.11	0.42	0.75	0.83	3.98	1	1	1	38.08	35.34	18.26	39.82	37.17	23.24	4.35	7.01	20.93
2021	44.965	0.1	0.11	0.42	0.75	0.83	3.98	1	1	1	38.08	35.34	18.26	39.82	37.17	23.24	5.14	7.80	21.72
2022	45.755	0.1	0.11	0.42	0.75	0.83	3.98	1	1	1	38.08	35.34	18.26	39.82	37.17	23.24	5.93	8.59	22.51
2023	46.545	0.1	0.12	0.43	0.75	0.91	4.07	1	1	1	38.08	35.34	18.26	39.82	37.24	23.34	6.72	9.30	23.21
2024	47.335	0.11	0.12	0.43	0.82	0.91	4.07	1	1	1	38.08	35.34	18.26	39.90	37.24	23.34	7.44	10.09	24.00
2025	48.125	0.11	0.12	0.44	0.82	0.91	4.17	1	1	1	38.08	35.34	18.26	39.90	37.24	23.43	8.23	10.88	24.69
2026	48.915	0.11	0.12	0.44	0.82	0.91	4.17	1	1	1	38.08	35.34	18.26	39.90	37.24	23.43	9.02	11.67	25.48
2027	49.705	0.11	0.13	0.45	0.82	0.98	4.26	1	1	1	38.08	35.34	18.26	39.90	37.32	23.53	9.81	12.39	26.18
2028	50.495	0.12	0.13	0.45	0.90	0.98	4.26	1	1	1	38.08	35.34	18.26	39.97	37.32	23.53	10.52	13.18	26.97
2029	51.285	0.12	0.13	0.45	0.90	0.98	4.26	1	1	1	38.08	35.34	18.26	39.97	37.32	23.53	11.31	13.97	27.76
2030	52.075	0.12	0.13	0.46	0.90	0.98	4.36	1	1	1	38.08	35.34	18.26	39.97	37.32	23.62	12.10	14.76	28.45
2031	52.865	0.12	0.14	0.46	0.90	1.06	4.36	1	1	1	38.08	35.34	18.26	39.97	37.40	23.62	12.89	15.47	29.24
2032	53.655		0.14			1.06			1			35.34			37.40			16.26	

	Hazelwood	NPAT (Tax @ 21%)			Yallourn	NPAT (Tax @ 21%)			Emissions (kt) BAU		Emissions 1t-e CO2 std (kt)			Emissions Saved (kt)		
FY	Gen (MWh)	Profit (NPV)	Lost profit (NPV)	Cost/MWh	Gen (MWh)	Profit (NPV)	Lost profit (cost)	Cost/MWh	Hazelwood	Yallourn	Hazelwoo	Yallourn	Make-up	Hazelwood	Yallourn	Total
2016	6412549	$ 6,412,741.31	$102,860,621.74	$ 16.04	6391099	$ 19,801,704.40	$ 87,292,793.05	$ 13.66	15011	12887	9811	9075	6200	5200	3812	2811
2017	6412549	$ 10,414,813.15	$104,981,719.82	$ 16.37	6391099	$ 23,790,389.03	$ 88,968,040.60	$ 13.92	15011	12887	9811	9075	6200	5200	3812	2811
2018	6412549	$ 14,416,885.00	$107,102,817.90	$ 16.70	6391099	$ 27,397,791.10	$ 90,255,752.54	$ 14.12	15011	12887	9811	9075	6200	5200	3812	2811
2019	6412549	$ 18,039,690.57	$108,715,357.83	$ 16.95	6391099	$ 31,386,475.73	$ 91,931,000.09	$ 14.38	15011	12887	9811	9075	6200	5200	3812	2811
2020	6412549	$ 22,041,762.42	$110,836,455.91	$ 17.28	6391099	$ 35,375,160.36	$ 93,606,247.63	$ 14.65	15011	12887	9811	9075	6200	5200	3812	2811
2021	6412549	$ 26,043,834.26	$112,957,553.99	$ 17.62	6391099	$ 39,363,844.99	$ 95,281,495.18	$ 14.91	15011	12887	9811	9075	6200	5200	3812	2811
2022	6412549	$ 30,045,906.10	$115,078,652.07	$ 17.95	6391099	$ 43,352,529.62	$ 96,956,742.72	$ 15.17	15011	12887	9811	9075	6200	5200	3812	2811
2023	6412549	$ 34,047,977.95	$117,199,750.14	$ 18.28	6391099	$ 46,959,931.69	$ 98,244,454.67	$ 15.37	15011	12887	9811	9075	6200	5200	3812	2811
2024	6412549	$ 37,670,783.52	$118,812,290.08	$ 18.53	6391099	$ 50,948,616.32	$ 99,919,702.22	$ 15.63	15011	12887	9811	9075	6200	5200	3812	2811
2025	6412549	$ 41,672,855.36	$120,933,388.16	$ 18.86	6391099	$ 54,937,300.95	$ 101,594,949.76	$ 15.90	15011	12887	9811	9075	6200	5200	3812	2811
2026	6412549	$ 45,674,927.21	$123,054,486.23	$ 19.19	6391099	$ 58,925,985.58	$ 103,270,197.31	$ 16.16	15011	12887	9811	9075	6200	5200	3812	2811
2027	6412549	$ 49,676,999.05	$125,175,584.31	$ 19.52	6391099	$ 62,533,387.65	$ 104,557,909.26	$ 16.36	15011	12887	9811	9075	6200	5200	3812	2811
2028	6412549	$ 53,299,804.62	$126,788,124.25	$ 19.77	6391099	$ 66,522,072.28	$ 106,233,156.80	$ 16.62	15011	12887	9811	9075	6200	5200	3812	2811
2029	6412549	$ 57,301,876.47	$128,909,222.33	$ 20.10	6391099	$ 70,510,756.92	$ 107,908,404.35	$ 16.88	15011	12887	9811	9075	6200	5200	3812	2811
2030	6412549	$ 61,303,948.31	$131,030,320.40	$ 20.43	6391099	$ 74,499,441.55	$ 109,583,651.89	$ 17.15	15011	12887	9811	9075	6200	5200	3812	2811
2031	6412549	$ (367,693,979.85)	$133,151,418.48	$ 20.76	6391099	$ 78,106,843.62	$ 110,871,363.84	$ 17.35	15011	12887	9811	9075	6200	5200	3812	2811
2032					6391099	$(235,304,471.75)	$ 112,546,611.39	$ 17.61		12887		9075			3812	
Operational Life Totals	**102,600,784**	**$131,001,918.20**	**$951,028,642.72**		**108,648,676**	**$295,611,533.54**	**$826,857,005.45**		**240,178**	**219,079**	**156,979**	**154,281**	**99,207**	**83,199**	**64,798**	**44,978**

2. Medium Standard: 1.1 tCO_2-e/MWh

Forecast Electricity prices		Fuel Costs $/GJ			Fuel Costs $/MWh			VOM			FOM			Average costs $/MWh			Margins		
FY	E(Pw)	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B
2016	41.015	0.09	0.1	0.4	0.74	0.83	3.79	1	1	1	34.61	32.13	18.26	36.36	33.96	23.05	4.66	7.06	17.96
2017	41.805	0.09	0.1	0.4	0.74	0.83	3.79	1	1	1	34.61	32.13	18.26	36.36	33.96	23.05	5.45	7.85	18.75
2018	42.595	0.09	0.11	0.41	0.74	0.91	3.88	1	1	1	34.61	32.13	18.26	36.36	34.04	23.15	6.24	8.56	19.45
2019	43.385	0.1	0.11	0.41	0.82	0.91	3.88	1	1	1	34.61	32.13	18.26	36.44	34.04	23.15	6.95	9.35	20.24
2020	44.175	0.1	0.11	0.42	0.82	0.91	3.98	1	1	1	34.61	32.13	18.26	36.44	34.04	23.24	7.74	10.14	20.93
2021	44.965	0.1	0.11	0.42	0.82	0.91	3.98	1	1	1	34.61	32.13	18.26	36.44	34.04	23.24	8.53	10.93	21.72
2022	45.755	0.1	0.11	0.42	0.82	0.91	3.98	1	1	1	34.61	32.13	18.26	36.44	34.04	23.24	9.32	11.72	22.51
2023	46.545	0.1	0.12	0.43	0.82	1.00	4.07	1	1	1	34.61	32.13	18.26	36.44	34.12	23.34	10.11	12.42	23.21
2024	47.335	0.11	0.12	0.43	0.91	1.00	4.07	1	1	1	34.61	32.13	18.26	36.52	34.12	23.34	10.82	13.21	24.00
2025	48.125	0.11	0.12	0.44	0.91	1.00	4.17	1	1	1	34.61	32.13	18.26	36.52	34.12	23.43	11.61	14.00	24.69
2026	48.915	0.11	0.12	0.44	0.91	1.00	4.17	1	1	1	34.61	32.13	18.26	36.52	34.12	23.43	12.40	14.79	25.48
2027	49.705	0.11	0.13	0.45	0.91	1.08	4.26	1	1	1	34.61	32.13	18.26	36.52	34.21	23.53	13.19	15.50	26.18
2028	50.495	0.12	0.13	0.45	0.99	1.08	4.26	1	1	1	34.61	32.13	18.26	36.60	34.21	23.53	13.89	16.29	26.97
2029	51.285	0.12	0.13	0.45	0.99	1.08	4.26	1	1	1	34.61	32.13	18.26	36.60	34.21	23.53	14.68	17.08	27.76
2030	52.075	0.12	0.13	0.46	0.99	1.08	4.36	1	1	1	34.61	32.13	18.26	36.60	34.21	23.62	15.47	17.87	28.45
2031	52.865	0.12	0.14	0.46	0.99	1.16	4.36	1	1	1	34.61	32.13	18.26	36.60	34.29	23.62	16.26	18.58	29.24
2032	53.655		0.14			1.16			1			32.13			34.29			19.37	

	Hazelwood				Yallourn	NPAT (Tax @ 21%)			Emissions (kt) BAU		Emissions with 1.1 e std (kt)			Emissions Saved (kt)		
FY	Gen (MWh)	Profit	Lost profit (cost)	Cost/MWh	Gen (MWh)	Profit	Lost profit (cost)	Cost/MWh	Hazelwood	Yallourn	Hazelwoo	Yallourn	Make-up	Hazelwood	Yallourn	Total
2016	7053804	$ 25,967,181.84	$ 83,306,181.22	$ 11.81	7030208	$ 39,204,456.02	$ 67,890,041.43	$ 9.66	15011	12887	10792	9983	5035	4219	2904	2088
2017	7053804	$ 30,369,460.86	$ 85,027,072.11	$ 12.05	7030208	$ 43,592,009.11	$ 69,166,420.51	$ 9.84	15011	12887	10792	9983	5035	4219	2904	2088
2018	7053804	$ 34,771,739.89	$ 86,747,963.00	$ 12.30	7030208	$ 47,518,210.31	$ 70,135,333.33	$ 9.98	15011	12887	10792	9983	5035	4219	2904	2088
2019	7053804	$ 38,715,106.73	$ 88,039,941.67	$ 12.48	7030208	$ 51,905,763.40	$ 71,411,712.42	$ 10.16	15011	12887	10792	9983	5035	4219	2904	2088
2020	7053804	$ 43,117,385.76	$ 89,760,832.56	$ 12.73	7030208	$ 56,293,316.50	$ 72,688,091.50	$ 10.34	15011	12887	10792	9983	5035	4219	2904	2088
2021	7053804	$ 47,519,664.79	$ 91,481,723.46	$ 12.97	7030208	$ 60,680,869.59	$ 73,964,470.58	$ 10.52	15011	12887	10792	9983	5035	4219	2904	2088
2022	7053804	$ 51,921,943.82	$ 93,202,614.35	$ 13.21	7030208	$ 65,068,422.68	$ 75,240,849.66	$ 10.70	15011	12887	10792	9983	5035	4219	2904	2088
2023	7053804	$ 56,324,222.84	$ 94,923,505.24	$ 13.46	7030208	$ 68,994,623.88	$ 76,209,762.49	$ 10.84	15011	12887	10792	9983	5035	4219	2904	2088
2024	7053804	$ 60,267,589.69	$ 96,215,483.91	$ 13.64	7030208	$ 73,382,176.97	$ 77,486,141.57	$ 11.02	15011	12887	10792	9983	5035	4219	2904	2088
2025	7053804	$ 64,669,868.72	$ 97,936,374.80	$ 13.88	7030208	$ 77,769,730.07	$ 78,762,520.65	$ 11.20	15011	12887	10792	9983	5035	4219	2904	2088
2026	7053804	$ 69,072,147.74	$ 99,657,265.70	$ 14.13	7030208	$ 82,157,283.16	$ 80,038,899.73	$ 11.38	15011	12887	10792	9983	5035	4219	2904	2088
2027	7053804	$ 73,474,426.77	$101,378,156.59	$ 14.37	7030208	$ 86,083,484.36	$ 81,007,812.56	$ 11.52	15011	12887	10792	9983	5035	4219	2904	2088
2028	7053804	$ 77,417,793.61	$102,670,135.26	$ 14.56	7030208	$ 90,471,037.45	$ 82,284,191.64	$ 11.70	15011	12887	10792	9983	5035	4219	2904	2088
2029	7053804	$ 81,820,072.64	$104,391,026.15	$ 14.80	7030208	$ 94,858,590.54	$ 83,560,570.72	$ 11.89	15011	12887	10792	9983	5035	4219	2904	2088
2030	7053804	$ 86,222,351.67	$106,111,917.04	$ 15.04	7030208	$ 99,246,143.64	$ 84,836,949.80	$ 12.07	15011	12887	10792	9983	5035	4219	2904	2088
2031	7053804	$ (342,375,369.30)	$107,832,807.94	$ 15.29	7030208	$ 103,172,344.83	$ 85,805,862.63	$ 12.21	15011	12887	10792	9983	5035	4219	2904	2088
2032					7030208	$(209,840,102.07)	$ 87,082,241.71	$ 12.39		12887		9983			2904	
Operational Life Totals	**112,860,863**	**$311,819,737.84**	**$770,210,823.08**		**119,513,544**	**$480,834,101.64**	**$641,634,437.35**		**240,178**	**219,079**	**172,677**	**169,709**	**80,565**	**67,501**	**49,370**	**33,402**

3. Weak Standard: 1.2 tCO_2-e/MWh

Forecast Electricity prices		Fuel Costs $/GJ			Fuel Costs $/MWh			VOM			FOM			Average costs $/MWh			Margins		
FY	E(Pw)	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B	H	Y	LY B
2016	41.015	0.09	0.1	0.4	0.81	0.91	3.79	1	1	1	31.73	29.45	18.26	33.54	31.35	23.05	7.48	9.66	17.96
2017	41.805	0.09	0.1	0.4	0.81	0.91	3.79	1	1	1	31.73	29.45	18.26	33.54	31.35	23.05	8.27	10.45	18.75
2018	42.595	0.09	0.11	0.41	0.81	1.00	3.88	1	1	1	31.73	29.45	18.26	33.54	31.45	23.15	9.06	11.15	19.45
2019	43.385	0.1	0.11	0.41	0.90	1.00	3.88	1	1	1	31.73	29.45	18.26	33.63	31.45	23.15	9.76	11.94	20.24
2020	44.175	0.1	0.11	0.42	0.90	1.00	3.98	1	1	1	31.73	29.45	18.26	33.63	31.45	23.24	10.55	12.73	20.93
2021	44.965	0.1	0.11	0.42	0.90	1.00	3.98	1	1	1	31.73	29.45	18.26	33.63	31.45	23.24	11.34	13.52	21.72
2022	45.755	0.1	0.11	0.42	0.90	1.00	3.98	1	1	1	31.73	29.45	18.26	33.63	31.45	23.24	12.13	14.31	22.51
2023	46.545	0.1	0.12	0.43	0.90	1.09	4.07	1	1	1	31.73	29.45	18.26	33.63	31.54	23.34	12.92	15.01	23.21
2024	47.335	0.11	0.12	0.43	0.99	1.09	4.07	1	1	1	31.73	29.45	18.26	33.72	31.54	23.34	13.62	15.80	24.00
2025	48.125	0.11	0.12	0.44	0.99	1.09	4.17	1	1	1	31.73	29.45	18.26	33.72	31.54	23.43	14.41	16.59	24.69
2026	48.915	0.11	0.12	0.44	0.99	1.09	4.17	1	1	1	31.73	29.45	18.26	33.72	31.54	23.43	15.20	17.38	25.48
2027	49.705	0.11	0.13	0.45	0.99	1.18	4.26	1	1	1	31.73	29.45	18.26	33.72	31.63	23.53	15.99	18.08	26.18
2028	50.495	0.12	0.13	0.45	1.08	1.18	4.26	1	1	1	31.73	29.45	18.26	33.81	31.63	23.53	16.69	18.87	26.97
2029	51.285	0.12	0.13	0.45	1.08	1.18	4.26	1	1	1	31.73	29.45	18.26	33.81	31.63	23.53	17.48	19.66	27.76
2030	52.075	0.12	0.13	0.46	1.08	1.18	4.36	1	1	1	31.73	29.45	18.26	33.81	31.63	23.62	18.27	20.45	28.45
2031	52.865	0.12	0.14	0.46	1.08	1.27	4.36	1	1	1	31.73	29.45	18.26	33.81	31.72	23.62	19.06	21.15	29.24
2032	53.655		0.14			1.27			1			29.45			31.72			21.94	

	Hazelwood				Yallourn	NPAT (Tax @ 21%)			Emissions (kt) BAU		Emissions (kt) with 1.2 e std			Emissions Saved (kt)		
FY	Generation (M	Profit	Lost profit (cost)	Cost/MWh	Gerneration (	Profit	Lost profit (cost)	Cost/MWh	Hazelwood	Yallourn	Hazelwoo	Yallourn	Make-up	Hazelwood	Yallourn	Total
2016	7695059	$ 45,453,354.43	$ 63,820,008.62	$ 8.29	7669318	$ 58,530,951.13	$ 48,563,546.32	$ 6.33	15011	12887	11773	10890	3870	3238	1997	1364
2017	7695059	$ 50,255,840.65	$ 65,140,692.33	$ 8.47	7669318	$ 63,317,372.69	$ 49,441,056.94	$ 6.45	15011	12887	11773	10890	3870	3238	1997	1364
2018	7695059	$ 55,058,326.86	$ 66,461,376.04	$ 8.64	7669318	$ 67,554,747.35	$ 50,098,796.29	$ 6.53	15011	12887	11773	10890	3870	3238	1997	1364
2019	7695059	$ 59,314,669.64	$ 67,440,378.76	$ 8.76	7669318	$ 72,341,168.91	$ 50,976,306.91	$ 6.65	15011	12887	11773	10890	3870	3238	1997	1364
2020	7695059	$ 64,117,155.86	$ 68,761,062.47	$ 8.94	7669318	$ 77,127,590.47	$ 51,853,817.53	$ 6.76	15011	12887	11773	10890	3870	3238	1997	1364
2021	7695059	$ 68,919,642.07	$ 70,081,746.18	$ 9.11	7669318	$ 81,914,012.03	$ 52,731,328.14	$ 6.88	15011	12887	11773	10890	3870	3238	1997	1364
2022	7695059	$ 73,722,128.28	$ 71,402,429.89	$ 9.28	7669318	$ 86,700,433.58	$ 53,608,838.76	$ 6.99	15011	12887	11773	10890	3870	3238	1997	1364
2023	7695059	$ 78,524,614.49	$ 72,723,113.60	$ 9.45	7669318	$ 90,937,808.25	$ 54,266,578.11	$ 7.08	15011	12887	11773	10890	3870	3238	1997	1364
2024	7695059	$ 82,780,957.28	$ 73,702,116.32	$ 9.58	7669318	$ 95,724,229.81	$ 55,144,088.73	$ 7.19	15011	12887	11773	10890	3870	3238	1997	1364
2025	7695059	$ 87,583,443.49	$ 75,022,800.03	$ 9.75	7669318	$ 100,510,651.37	$ 56,021,599.35	$ 7.30	15011	12887	11773	10890	3870	3238	1997	1364
2026	7695059	$ 92,385,929.70	$ 76,343,483.74	$ 9.92	7669318	$ 105,297,072.92	$ 56,899,109.97	$ 7.42	15011	12887	11773	10890	3870	3238	1997	1364
2027	7695059	$ 97,188,415.91	$ 77,664,167.45	$ 10.09	7669318	$ 109,534,447.59	$ 57,556,849.32	$ 7.50	15011	12887	11773	10890	3870	3238	1997	1364
2028	7695059	$ 101,444,758.70	$ 78,643,170.18	$ 10.22	7669318	$ 114,320,869.15	$ 58,434,359.94	$ 7.62	15011	12887	11773	10890	3870	3238	1997	1364
2029	7695059	$ 106,247,244.91	$ 79,963,853.88	$ 10.39	7669318	$ 119,107,290.71	$ 59,311,870.56	$ 7.73	15011	12887	11773	10890	3870	3238	1997	1364
2030	7695059	$ 111,049,731.12	$ 81,284,537.59	$ 10.56	7669318	$ 123,893,712.26	$ 60,189,381.18	$ 7.85	15011	12887	11773	10890	3870	3238	1997	1364
2031	7695059	$ (317,147,782.67)	$ 82,605,221.30	$ 10.73	7669318	$ 128,131,086.93	$ 60,847,120.53	$ 7.93	15011	12887	11773	10890	3870	3238	1997	1364
2032					7669318	$(184,482,491.51)	$ 61,724,631.15	$ 8.05		12887		10890			1997	
Operational Life Totals	**123,120,941**	**$491,996,416.52**	**$590,034,144.41**		**130,378,411**	**$665,309,715.12**	**$457,158,823.88**		**240,178**	**219,079**	**188,375**	**185,137**	**61,923**	**51,803**	**33,942**	**21,825**

Appendix D – Disagreement Scenarios: Carbon Capture and Storage

1. Installed units: H =200MW/ Y=350MW

										@ 200/1600 and 350/1480)								(-10% parasite load)						(90% capture rate)				
Forecast Electricity prices		Fuel Costs $/GJ		Fuel Costs $/MWh		VOM $/MWh		FOM $/MWh		VOM (CCS) $/MW		FOM (CCS) $/MW		Average costs $/MWh		Margins $/MWh		Electricity Sent-Out MWh		NPAT (Tax @ 21%)		Emissions (kt) (no CCS)		Emissions (kt)		Emissions Saved (kt)		
FY	E(Pw)	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	Total
2016	41.015	0.09	0.1	1.03	1.07	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.31	28.71	12.71	12.30	9688560	8860740	$ (1,109,749,480.60)	$ (2,026,127,247.27)	15011	12887	13322	10144	1689	2743	4,432
2017	41.805	0.09	0.1	1.03	1.07	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.31	28.71	13.50	13.09	9688560	8860740	$ 103,298,817.01	$ 91,655,658.37	15011	12887	13322	10144	1689	2743	4,432
2018	42.595	0.09	0.11	1.03	1.18	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.31	28.82	14.29	13.78	9688560	8860740	$ 109,345,447.31	$ 96,435,009.56	15011	12887	13322	10144	1689	2743	4,432
2019	43.385	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.42	28.82	14.96	14.57	9688560	8860740	$ 114,515,351.00	$ 101,964,997.40	15011	12887	13322	10144	1689	2743	4,432
2020	44.175	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.42	28.82	15.75	15.36	9688560	8860740	$ 120,561,981.30	$ 107,494,985.23	15011	12887	13322	10144	1689	2743	4,432
2021	44.965	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.42	28.82	16.54	16.15	9688560	8860740	$ 126,608,611.59	$ 113,024,973.06	15011	12887	13322	10144	1689	2743	4,432
2022	45.755	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.42	28.82	17.33	16.94	9688560	8860740	$ 132,655,241.89	$ 118,554,960.90	15011	12887	13322	10144	1689	2743	4,432
2023	46.545	0.1	0.12	1.15	1.29	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.42	28.93	18.12	17.62	9688560	8860740	$ 138,701,872.19	$ 123,334,312.09	15011	12887	13322	10144	1689	2743	4,432
2024	47.335	0.11	0.12	1.26	1.29	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.54	28.93	18.80	18.41	9688560	8860740	$ 143,871,775.88	$ 128,864,299.92	15011	12887	13322	10144	1689	2743	4,432
2025	48.125	0.11	0.12	1.26	1.29	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.54	28.93	19.59	19.20	9688560	8860740	$ 149,918,406.18	$ 134,394,287.75	15011	12887	13322	10144	1689	2743	4,432
2026	48.915	0.11	0.12	1.26	1.29	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.54	28.93	20.38	19.99	9688560	8860740	$ 155,965,036.47	$ 139,924,275.59	15011	12887	13322	10144	1689	2743	4,432
2027	49.705	0.11	0.13	1.26	1.39	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.54	29.03	21.17	20.67	9688560	8860740	$ 162,011,666.77	$ 144,703,626.78	15011	12887	13322	10144	1689	2743	4,432
2028	50.495	0.12	0.13	1.37	1.39	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.65	29.03	21.84	21.46	9688560	8860740	$ 167,181,570.46	$ 150,233,614.61	15011	12887	13322	10144	1689	2743	4,432
2029	51.285	0.12	0.13	1.37	1.39	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.65	29.03	22.63	22.25	9688560	8860740	$ 173,228,200.76	$ 155,763,602.44	15011	12887	13322	10144	1689	2743	4,432
2030	52.075	0.12	0.13	1.37	1.39	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.65	29.03	23.42	23.04	9688560	8860740	$ 179,274,831.05	$ 161,293,590.28	15011	12887	13322	10144	1689	2743	4,432
2031	52.865	0.12	0.14	1.37	1.50	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.65	29.14	24.21	23.72	9688560	8860740	$ 185,321,461.35	$ 166,072,941.46	15011	12887	13322	10144	1689	2743	4,432
2032	53.655	0.12	0.14	1.37	1.50	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.65	29.14	25.00	24.51	9688560	8860740	$ 191,368,091.65	$ 171,602,929.30	15011	12887	13322	10144	1689	2743	4,432
2033	54.445	0.13	0.14	1.49	1.50	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.77	29.14	25.68	25.30	9688560	8860740	$ 196,537,995.34	$ 177,132,917.13	15011	12887	13322	10144	1689	2743	4,432
2034	55.235	0.13	0.14	1.49	1.50	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.77	29.14	26.47	26.09	9688560	8860740	$ 202,584,625.64	$ 182,662,904.97	15011	12887	13322	10144	1689	2743	4,432
2035	56.025	0.13	0.15	1.49	1.61	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.77	29.25	27.26	26.78	9688560	8860740	$ 208,631,255.93	$ 187,442,256.15	15011	12887	13322	10144	1689	2743	4,432
2036	56.815	0.13	0.15	1.49	1.61	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.77	29.25	28.05	27.57	9688560	8860740	$ 214,677,886.23	$ 192,972,243.99	15011	12887	13322	10144	1689	2743	4,432
2037	57.605	0.14	0.15	1.60	1.61	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.88	29.25	28.72	28.36	9688560	8860740	$ 219,847,789.92	$ 198,502,231.82	15011	12887	13322	10144	1689	2743	4,432
2038	58.395	0.14	0.16	1.60	1.72	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.88	29.35	29.51	29.04	9688560	8860740	$ 225,894,420.22	$ 203,281,583.01	15011	12887	13322	10144	1689	2743	4,432
2039	59.185	0.14	0.16	1.60	1.72	1	1	24.89	24.01	0.75	1.42	0.64	1.21	28.88	29.35	30.30	29.83	9688560	8860740	$ 231,941,050.51	$ 208,811,570.84	15011	12887	13322	10144	1689	2743	4,432
2040	59.975	0.15	0.16	1.72	1.72	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.00	29.35	30.98	30.62	9688560	8860740	$ 237,110,954.21	$ 214,341,558.68	15011	12887	13322	10144	1689	2743	4,432
2041	60.765	0.15	0.17	1.72	1.82	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.00	29.46	31.77	31.30	9688560	8860740	$ 243,157,584.50	$ 219,120,909.87	15011	12887	13322	10144	1689	2743	4,432
2042	61.555	0.15	0.17	1.72	1.82	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.00	29.46	32.56	32.09	9688560	8860740	$ 249,204,214.80	$ 224,650,897.70	15011	12887	13322	10144	1689	2743	4,432
2043	62.345	0.15	0.17	1.72	1.82	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.00	29.46	33.35	32.88	9688560	8860740	$ 255,250,845.10	$ 230,180,885.53	15011	12887	13322	10144	1689	2743	4,432
2044	63.135	0.16	0.17	1.83	1.82	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.11	29.46	34.02	33.67	9688560	8860740	$ 260,420,748.79	$ 235,710,873.37	15011	12887	13322	10144	1689	2743	4,432
2045	63.925	0.16	0.18	1.83	1.93	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.11	29.57	34.81	34.36	9688560	8860740	$ 266,467,379.09	$ 240,490,224.56	15011	12887	13322	10144	1689	2743	4,432
2046	64.715	0.16	0.18	1.83	1.93	1	1	24.89	24.01	0.75	1.42	0.64	1.21	29.11	29.57	35.60	35.15	9688560	8860740	$ (160,485,990.62)	$ 246,020,212.39	15011	12887	13322	10144	1689	2743	4,432
2047	65.505		0.18		1.93		1		24.01		1.42		1.21		29.57		35.94		8860740		$ (65,849,799.78)		12887		10144		2743	2,743
																Operating Life Total		**300345360**	**283543680**	**$ 402,332,267**	**$ (564,465,752)**	**465345**	**412384**	**412994**	**324613**	**52351**	**87771**	**140122**
																				NPVs @ 9%								

2. Installed units: H =400MW/ Y=350MW

										@ 400/1600 and 350/1480)					
Forecast Electricity prices		Fuel Costs $/GJ		Fuel Costs $/MWh		VOM $/MWh		FOM $/MWh		VOM (CCS) $/MW		FOM (CCS) $/MW		Average costs $/MWh	
FY	E(Pw)	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y
2016	41.015	0.09	0.1	1.03	1.07	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.70	28.71
2017	41.805	0.09	0.1	1.03	1.07	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.70	28.71
2018	42.595	0.09	0.11	1.03	1.18	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.70	28.82
2019	43.385	0.1	0.11	1.15	1.18	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.82	28.82
2020	44.175	0.1	0.11	1.15	1.18	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.82	28.82
2021	44.965	0.1	0.11	1.15	1.18	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.82	28.82
2022	45.755	0.1	0.11	1.15	1.18	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.82	28.82
2023	46.545	0.1	0.12	1.15	1.29	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.82	28.93
2024	47.335	0.11	0.12	1.26	1.29	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.93	28.93
2025	48.125	0.11	0.12	1.26	1.29	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.93	28.93
2026	48.915	0.11	0.12	1.26	1.29	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.93	28.93
2027	49.705	0.11	0.13	1.26	1.39	1	1	24.89	24.01	1.50	1.42	1.28	1.21	29.93	29.03
2028	50.495	0.12	0.13	1.37	1.39	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.04	29.03
2029	51.285	0.12	0.13	1.37	1.39	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.04	29.03
2030	52.075	0.12	0.13	1.37	1.39	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.04	29.03
2031	52.865	0.12	0.14	1.37	1.50	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.04	29.14
2032	53.655	0.12	0.14	1.37	1.50	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.04	29.14
2033	54.445	0.13	0.14	1.49	1.50	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.16	29.14
2034	55.235	0.13	0.14	1.49	1.50	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.16	29.14
2035	56.025	0.13	0.15	1.49	1.61	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.16	29.25
2036	56.815	0.13	0.15	1.49	1.61	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.16	29.25
2037	57.605	0.14	0.15	1.60	1.61	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.27	29.25
2038	58.395	0.14	0.16	1.60	1.72	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.27	29.35
2039	59.185	0.14	0.16	1.60	1.72	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.27	29.35
2040	59.975	0.15	0.16	1.72	1.72	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.39	29.35
2041	60.765	0.15	0.17	1.72	1.82	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.39	29.46
2042	61.555	0.15	0.17	1.72	1.82	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.39	29.46
2043	62.345	0.15	0.17	1.72	1.82	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.39	29.46
2044	63.135	0.16	0.17	1.83	1.82	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.50	29.46
2045	63.925	0.16	0.18	1.83	1.93	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.50	29.57
2046	64.715	0.16	0.18	1.83	1.93	1	1	24.89	24.01	1.50	1.42	1.28	1.21	30.50	29.57
2047	65.505		0.18		1.93		1		24.01		1.42		1.21		29.57

			(-10% parasite load)						(90% capture rate)				
	Margins $/MWh		Electricity Sent-Out MWh		NPAT (Tax @ 21%)		Emissions (kt) (no CCS)		Emissions (kt)		Emissions Saved (kt)		
FY	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	Total
2016	11.31	12.30	9565920	8860740	$ (2,328,502,570.86)	$ (2,026,127,247.27)	15011	12887	11634	10144	3378	2743	6,120
2017	12.10	13.09	9565920	8860740	$ 91,470,854.45	$ 91,655,658.37	15011	12887	11634	10144	3378	2743	6,120
2018	12.89	13.78	9565920	8860740	$ 97,440,945.12	$ 96,435,009.56	15011	12887	11634	10144	3378	2743	6,120
2019	13.57	14.57	9565920	8860740	$ 102,545,407.00	$ 101,964,997.40	15011	12887	11634	10144	3378	2743	6,120
2020	14.36	15.36	9565920	8860740	$ 108,515,497.67	$ 107,494,985.23	15011	12887	11634	10144	3378	2743	6,120
2021	15.15	16.15	9565920	8860740	$ 114,485,588.34	$ 113,024,973.06	15011	12887	11634	10144	3378	2743	6,120
2022	15.94	16.94	9565920	8860740	$ 120,455,679.01	$ 118,554,960.90	15011	12887	11634	10144	3378	2743	6,120
2023	16.73	17.62	9565920	8860740	$ 126,425,769.69	$ 123,334,312.09	15011	12887	11634	10144	3378	2743	6,120
2024	17.40	18.41	9565920	8860740	$ 131,530,231.56	$ 128,864,299.92	15011	12887	11634	10144	3378	2743	6,120
2025	18.19	19.20	9565920	8860740	$ 137,500,322.23	$ 134,394,287.75	15011	12887	11634	10144	3378	2743	6,120
2026	18.98	19.99	9565920	8860740	$ 143,470,412.90	$ 139,924,275.59	15011	12887	11634	10144	3378	2743	6,120
2027	19.77	20.67	9565920	8860740	$ 149,440,503.58	$ 144,703,626.78	15011	12887	11634	10144	3378	2743	6,120
2028	20.45	21.46	9565920	8860740	$ 154,544,965.45	$ 150,233,614.61	15011	12887	11634	10144	3378	2743	6,120
2029	21.24	22.25	9565920	8860740	$ 160,515,056.12	$ 155,763,602.44	15011	12887	11634	10144	3378	2743	6,120
2030	22.03	23.04	9565920	8860740	$ 166,485,146.79	$ 161,293,590.28	15011	12887	11634	10144	3378	2743	6,120
2031	22.82	23.72	9565920	8860740	$ 172,455,237.47	$ 166,072,941.46	15011	12887	11634	10144	3378	2743	6,120
2032	23.61	24.51	9565920	8860740	$ 178,425,328.14	$ 171,602,929.30	15011	12887	11634	10144	3378	2743	6,120
2033	24.29	25.30	9565920	8860740	$ 183,529,790.01	$ 177,132,917.13	15011	12887	11634	10144	3378	2743	6,120
2034	25.08	26.09	9565920	8860740	$ 189,499,880.69	$ 182,662,904.97	15011	12887	11634	10144	3378	2743	6,120
2035	25.87	26.78	9565920	8860740	$ 195,469,971.36	$ 187,442,256.15	15011	12887	11634	10144	3378	2743	6,120
2036	26.66	27.57	9565920	8860740	$ 201,440,062.03	$ 192,972,243.99	15011	12887	11634	10144	3378	2743	6,120
2037	27.33	28.36	9565920	8860740	$ 206,544,523.90	$ 198,502,231.82	15011	12887	11634	10144	3378	2743	6,120
2038	28.12	29.04	9565920	8860740	$ 212,514,614.58	$ 203,281,583.01	15011	12887	11634	10144	3378	2743	6,120
2039	28.91	29.83	9565920	8860740	$ 218,484,705.25	$ 208,811,570.84	15011	12887	11634	10144	3378	2743	6,120
2040	29.59	30.62	9565920	8860740	$ 223,589,167.12	$ 214,341,558.68	15011	12887	11634	10144	3378	2743	6,120
2041	30.38	31.30	9565920	8860740	$ 229,559,257.80	$ 219,120,909.87	15011	12887	11634	10144	3378	2743	6,120
2042	31.17	32.09	9565920	8860740	$ 235,529,348.47	$ 224,650,897.70	15011	12887	11634	10144	3378	2743	6,120
2043	31.96	32.88	9565920	8860740	$ 241,499,439.14	$ 230,180,885.53	15011	12887	11634	10144	3378	2743	6,120
2044	32.63	33.67	9565920	8860740	$ 246,603,901.01	$ 235,710,873.37	15011	12887	11634	10144	3378	2743	6,120
2045	33.42	34.36	9565920	8860740	$ 252,573,991.69	$ 240,490,224.56	15011	12887	11634	10144	3378	2743	6,120
2046	34.21	35.15	9565920	8860740	$ (174,455,917.64)	$ 246,020,212.39	15011	12887	11634	10144	3378	2743	6,120
2047		35.94		8860740		$ (65,849,799.78)		12887		10144		2743	2,743
	Operating Life Total		**296543520**	**283543680**	**$ (833,307,733)**	**$ (564,465,752)**	**465345**	**412384**	**360643**	**324613**	**104703**	**87771**	**192474**
					NPVs @ 9%								

3. Installed units: H =600MW/ Y=700MW

										@ 600/1600 and 700/1480)								(-10% parasite load)						(90% capture rate)				
Forecast Electricity prices		Fuel Costs $/GJ		Fuel Costs $/MWh		VOM $/MWh		FOM $/MWh		VOM (CCS) $/MW		FOM (CCS) $/MW		Average costs $/MWh		Margins $/MWh		Electricity Sent-Out MWh		Profit		Emissions (kt) (no CCS)		Emissions (kt)		Emissions Saved (kt)		
FY	E(Pw)	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	H	Y	Total
2016	41.015	0.09	0.1	1.03	1.07	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.59	31.35	11.42	9.67	9443280	8646120	$ (3,535,795,620.92)	$ (4,158,455,889.52)	15011	12887	9945	7401	5066	5486	10,552
2017	41.805	0.09	0.1	1.03	1.07	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.59	31.35	12.21	10.46	9443280	8646120	$ 91,102,932.09	$ 71,445,989.60	15011	12887	9945	7401	5066	5486	10,552
2018	42.595	0.09	0.11	1.03	1.18	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.59	31.45	13.00	11.14	9443280	8646120	$ 96,996,483.14	$ 76,109,577.96	15011	12887	9945	7401	5066	5486	10,552
2019	43.385	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.71	31.45	13.68	11.93	9443280	8646120	$ 102,035,503.19	$ 81,505,621.45	15011	12887	9945	7401	5066	5486	10,552
2020	44.175	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.71	31.45	14.47	12.72	9443280	8646120	$ 107,929,054.24	$ 86,901,664.94	15011	12887	9945	7401	5066	5486	10,552
2021	44.965	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.71	31.45	15.26	13.51	9443280	8646120	$ 113,822,605.29	$ 92,297,708.43	15011	12887	9945	7401	5066	5486	10,552
2022	45.755	0.1	0.11	1.15	1.18	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.71	31.45	16.05	14.30	9443280	8646120	$ 119,716,156.34	$ 97,693,751.92	15011	12887	9945	7401	5066	5486	10,552
2023	46.545	0.1	0.12	1.15	1.29	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.71	31.56	16.84	14.99	9443280	8646120	$ 125,609,707.38	$ 102,357,340.28	15011	12887	9945	7401	5066	5486	10,552
2024	47.335	0.11	0.12	1.26	1.29	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.82	31.56	17.51	15.78	9443280	8646120	$ 130,648,727.44	$ 107,753,383.77	15011	12887	9945	7401	5066	5486	10,552
2025	48.125	0.11	0.12	1.26	1.29	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.82	31.56	18.30	16.57	9443280	8646120	$ 136,542,278.49	$ 113,149,427.26	15011	12887	9945	7401	5066	5486	10,552
2026	48.915	0.11	0.12	1.26	1.29	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.82	31.56	19.09	17.36	9443280	8646120	$ 142,435,829.54	$ 118,545,470.76	15011	12887	9945	7401	5066	5486	10,552
2027	49.705	0.11	0.13	1.26	1.39	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.82	31.67	19.88	18.04	9443280	8646120	$ 148,329,380.58	$ 123,209,059.11	15011	12887	9945	7401	5066	5486	10,552
2028	50.495	0.12	0.13	1.37	1.39	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.94	31.67	20.56	18.83	9443280	8646120	$ 153,368,400.64	$ 128,605,102.60	15011	12887	9945	7401	5066	5486	10,552
2029	51.285	0.12	0.13	1.37	1.39	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.94	31.67	21.35	19.62	9443280	8646120	$ 159,261,951.69	$ 134,001,146.10	15011	12887	9945	7401	5066	5486	10,552
2030	52.075	0.12	0.13	1.37	1.39	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.94	31.67	22.14	20.41	9443280	8646120	$ 165,155,502.74	$ 139,397,189.59	15011	12887	9945	7401	5066	5486	10,552
2031	52.865	0.12	0.14	1.37	1.50	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.94	31.77	22.93	21.09	9443280	8646120	$ 171,049,053.78	$ 144,060,777.94	15011	12887	9945	7401	5066	5486	10,552
2032	53.655	0.12	0.14	1.37	1.50	1	1	24.89	24.01	0.75	2.84	1.93	2.43	29.94	31.77	23.72	21.88	9443280	8646120	$ 176,942,604.83	$ 149,456,821.44	15011	12887	9945	7401	5066	5486	10,552
2033	54.445	0.13	0.14	1.49	1.50	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.05	31.77	24.39	22.67	9443280	8646120	$ 181,981,624.89	$ 154,852,864.93	15011	12887	9945	7401	5066	5486	10,552
2034	55.235	0.13	0.14	1.49	1.50	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.05	31.77	25.18	23.46	9443280	8646120	$ 187,875,175.94	$ 160,248,908.42	15011	12887	9945	7401	5066	5486	10,552
2035	56.025	0.13	0.15	1.49	1.61	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.05	31.88	25.97	24.14	9443280	8646120	$ 193,768,726.98	$ 164,912,496.78	15011	12887	9945	7401	5066	5486	10,552
2036	56.815	0.13	0.15	1.49	1.61	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.05	31.88	26.76	24.93	9443280	8646120	$ 199,662,278.03	$ 170,308,540.27	15011	12887	9945	7401	5066	5486	10,552
2037	57.605	0.14	0.15	1.60	1.61	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.17	31.88	27.44	25.72	9443280	8646120	$ 204,701,298.09	$ 175,704,583.76	15011	12887	9945	7401	5066	5486	10,552
2038	58.395	0.14	0.16	1.60	1.72	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.17	31.99	28.23	26.41	9443280	8646120	$ 210,594,849.14	$ 180,368,172.12	15011	12887	9945	7401	5066	5486	10,552
2039	59.185	0.14	0.16	1.60	1.72	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.17	31.99	29.02	27.20	9443280	8646120	$ 216,488,400.18	$ 185,764,215.61	15011	12887	9945	7401	5066	5486	10,552
2040	59.975	0.15	0.16	1.72	1.72	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.28	31.99	29.69	27.99	9443280	8646120	$ 221,527,420.24	$ 191,160,259.10	15011	12887	9945	7401	5066	5486	10,552
2041	60.765	0.15	0.17	1.72	1.82	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.28	32.10	30.48	28.67	9443280	8646120	$ 227,420,971.29	$ 195,823,847.46	15011	12887	9945	7401	5066	5486	10,552
2042	61.555	0.15	0.17	1.72	1.82	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.28	32.10	31.27	29.46	9443280	8646120	$ 233,314,522.34	$ 201,219,890.95	15011	12887	9945	7401	5066	5486	10,552
2043	62.345	0.15	0.17	1.72	1.82	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.28	32.10	32.06	30.25	9443280	8646120	$ 239,208,073.38	$ 206,615,934.44	15011	12887	9945	7401	5066	5486	10,552
2044	63.135	0.16	0.17	1.83	1.82	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.39	32.10	32.74	31.04	9443280	8646120	$ 244,247,093.44	$ 212,011,977.93	15011	12887	9945	7401	5066	5486	10,552
2045	63.925	0.16	0.18	1.83	1.93	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.39	32.20	33.53	31.72	9443280	8646120	$ 250,140,644.49	$ 216,675,566.29	15011	12887	9945	7401	5066	5486	10,552
2046	64.715	0.16	0.18	1.83	1.93	1	1	24.89	24.01	0.75	2.84	1.93	2.43	30.39	32.20	34.32	32.51	9443280	8646120	$ (176,965,804.46)	$ 222,071,609.78	15011	12887	9945	7401	5066	5486	10,552
2047	65.505		0.18		1.93		1		24.01		2.84		2.43		32.20		33.30		8646120		$ (89,932,346.73)		12887		7401		5486	5,486
																Operating Life Total		**292741680**	**276675840**	**$ (1,950,418,808)**	**$ (2,723,269,925)**	**465345**	**412384**	**308291**	**236842**	**157054**	**175542**	**332596**
																				NPVs @ 9%								