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Brown coal exit: A market mechanism for regulated closure of highly emissions intensive power stations

Frank Jotzo[a,*], Salim Mazouz[b]

[a] *Crawford School of Public Policy, Australian National University, JG Crawford Building, Acton, ACT 2601, Australia*
[b] *EcoPerspectives, Australia*

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ABSTRACT

In this paper we propose a market mechanism for regulated exit of highly emissions intensive power stations from the electricity grid. The starting point is that there is surplus capacity in coal fired power generation in Australia. In the absence of a carbon price signal, black coal generation capacity may leave the market instead of high emitting brown coal power stations. We lay out options for a mechanism of regulated power station closure using a market mechanism. Plants bid competitively over the payment they require for closure, the regulator chooses the most cost effective bid, and payment for closure is made by the remaining power stations in proportion to their carbon dioxide emissions. This could overcome adverse incentive effects for plants to stay in operation in anticipation of payment for closure and solve the political difficulties and problems of information asymmetry that plague government payments for closure and direct regulation for exit. We explore the issues theoretically and provide empirical illustrations. These suggest that closure of a brown coal fired power station in Australia could yield emissions savings at costs that are lower than the social benefits. The analysis in this paper is applicable to other countries.

1. Introduction

Many of the world's electricity grids have ageing and highly carbon dioxide emissions intensive coal-fired power plants. The short run marginal costs of the highly emissions intensive brown coal (lignite) power plants are low compared to black coal, gas and liquid fuel power plant (but higher than renewables). This is the case since there often is no alternative use for the brown coal mined in proximity to the power stations. Consequently brown coal plants operate for significant periods, increasing the emissions intensity of electricity supply. This is the case for Australia's fleet of brown coal fired power stations (Elliston et al., 2013; Byrnes et al., 2013), and similar examples exist in other countries (for example Germany, see IEA, 2011; Traber and Kemfert, 2011).

Where there is sufficient available capacity in lower-emissions plants, these plants could be closed down with benefits in terms of lower carbon dioxide emissions, and lessened local air pollution and other benefits for local amenity, including from ceasing associated open-cut mining activity. However such closure may not necessarily happen without policy intervention even in the face of overcapacity. Firstly, brown coal fired plants typically have lower short-run marginal costs of operation than the lower-emissions alternative of black coal and gas plants. These marginal costs dominate production decisions

* Corresponding author. [redacted]
E-mail addresses: [redacted]

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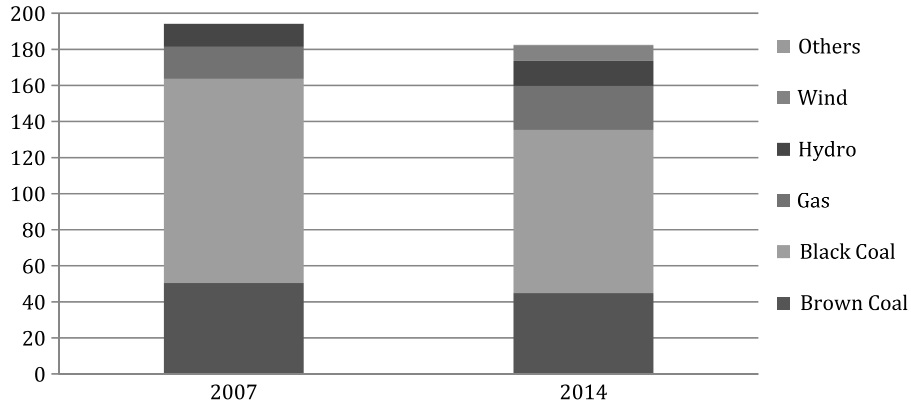

Fig. 1. Energy sent out in the NEM, Twh, 2007 and 2014. Data: The third party software NEMSight from Creative Analytics was used to extract AEMO data (Creative Analytics, 2015).

because investments were made in the past and are now sunk—in other words, once plants and mines are established, the operating costs of coal plants are mainly a function of fuel costs.

Secondly, there is a general impediment to exit: if one plant exits the market, the remaining ones will receive higher revenues. This acts as a disincentive to closure as every operator has an incentive to defer closure in the hope that another plant will close. Even if the gains to plants remaining on the grid were to outweigh the foregone gains to the exiting plant, the owners of power plants will typically not be able to achieve such an outcome without regulation, either because they cannot effectively co-ordinate or because competition law precludes them from such coordinated action.

The Australian National Electricity Market (NEM, the grid spanning the country's Eastern and Southern states) has overcapacity, as established by AEMO (2015). In recent years, overall electricity demand has reduced while renewable electricity generation – in particular wind power – has been added to the system (Fig. 1). From 2007 to 2014, average capacity utilization factors for black coal plants fell from 63% to 53%, for brown coal from 79% to 70%, and for gas fired generation from 31% to 26% (data from AEMO via NEMSight).

In this context, the Council of Australian Governments Energy Council considered the merits of reviving a 'payment for closure' policy pursued by the previous government (COAG, 2014). This policy aimed at providing funds to a (brown coal) generator to retire their generation capacity with a view to easing the excess capacity in the NEM as well as reducing emissions.[1] A variant of payment for closure of brown coal power plants is expected to be implemented in Germany, with payments of 230 million euros per year over a seven year period from electricity consumers to plant operators in return for taking 2.7GW of plant capacity out of production and placing the stations in reserve (Deutsche Welle, 2015).

In their communiqué dated 11 December 2014, the COAG Energy Council stated their lack of support for a contract-for-closure policy:

"…Nor does [the council] support assistance to generators to exit the market. The Council considers it is for the market to provide signals for investment and de-investment for generation, and opposes the transferral of the costs of retiring assets onto consumers or taxpayers".

The Australian Energy Market Commission (AEMC, 2015) also argued against intervention to facilitate plant exit:

"The evidence suggests that any barriers to exit have not deterred generators from commencing various stages of exit or the full retirement of plant. This would support leaving it to the market to determine which plant should exit".

These statements not withstanding, the issue of overcapacity and the possibility of government intervention to achieve 'orderly' exit remains on the agenda. For example, Nelson et al. (2015) assess barriers to exit and suggest various possible policy interventions to ameliorate outcomes compared with leaving market participants to make exit decisions. They argue that some operators mothball their plants rather than shutting them down permanently, and that this detracts from investment in renewable generating capacity. Nelson et al. (2015) see significant barriers to exit and a role for measures to facilitate closure of power plants to improve market stability and investment conditions in the electricity sector.

Such considerations are primarily concerned with market stability and investment conditions, and generally do not take account of climate change, or indeed of any other externalities. A case for government intervention could be made on grounds of greenhouse gas emissions. For instance, black coal in Australia has an average emissions factor of just over 0.9 tCO_2 per MWh generated, whereas brown coal based generation in Australia ranges from 1.2 to 1.5 tCO_2 per MWh, with an average of 1.3 tCO_2 per MWh. These emissions factors have stayed largely unchanged through time for each technology, however the total emissions intensity in the NEM fell due to the changes in composition especially the increase in renewables generation (Fig. 2). Capacity factors – the share of actual power output compared to what it would be if the plants ran every hour of the

[1] Under the 'payment for closure' scheme, government was to make negotiated payments to one or more plants in return for their closure. The scheme was announced but not implemented. Government cited overly high demands for payments as the reason for not following through.

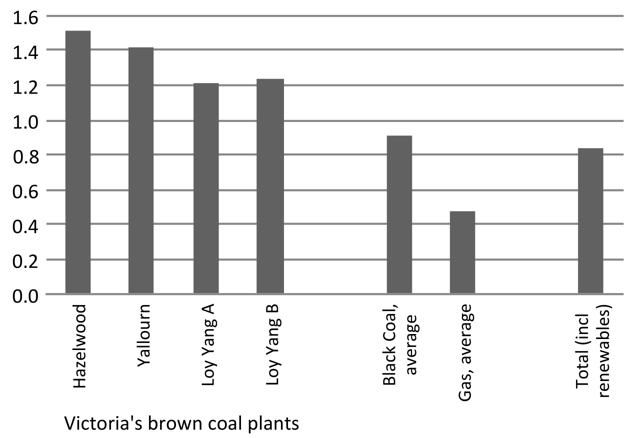

Fig. 2. Emissions intensity in the NEM, tCO2/Mwh, 2014. Data: The third party software NEMSight from Creative Analytics was used to extract AEMO data (Creative Analytics, 2015).

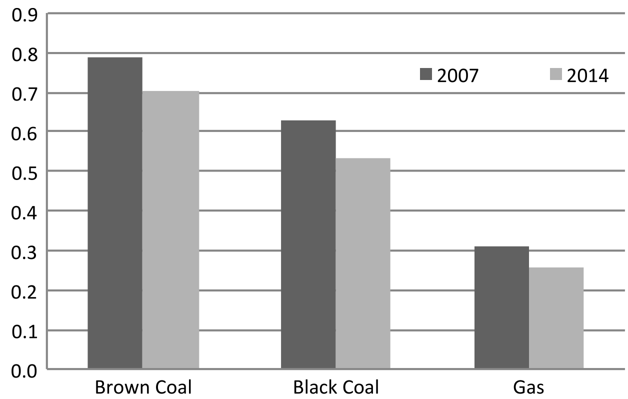

Fig. 3. Capacity factors in the NEM, 2007 and 2014. Data: The third party software NEMSight from Creative Analytics was used to extract AEMO data (Creative Analytics, 2015).

year at full capacity – has declined, for brown coal fired plants from 79% to 70% from 2007 to 2014, and from 63% to 53% for black coal fired plants, on average (Fig. 3).

If market outcomes led to the closure of black rather than brown coal generation capacity, emissions could be significantly higher than if brown coal plants closed.

That said, a prima facie case for intervention does not mean that any intervention that achieves the desired primary outcome is welfare enhancing. In the case of the payment for closure scheme, Riesz et al. (2013) question its merits and conclude that it should not be pursued. Their main argument is that payments for closure may create a vicious cycle that exacerbates barriers to exit. They argue that power plant operators will be looking to get paid to exit once the example is set, postponing exit because of perceived chances of future government payments.

Policy intervention aimed to facilitate early retirement of power generation plant must be well designed and implemented. If not there is the danger of wasting taxpayers' or consumers' money and introducing perverse incentives.

Economic theory holds that absent specific distortions or market failures, the first-best policy intervention is a carbon price, through an emissions trading scheme, carbon tax or similar arrangement, especially if it generates revenue that can be used to reduce other taxes (Helm and Pearce, 1990; Parry and Williams, 1999). A carbon price at a sufficient level can result in societally efficient exit of high-emissions plants, as the operating costs of the highest emissions intensive plants are increased by the greatest amount. By contrast, addition of renewable energy capacity may not result in efficient exit outcomes as it will tend to reduce revenue for all existing generators and may drive lower-emissions plant to close.

A carbon price was in place in Australia during 2012–14 but was abolished. Existing policies aimed at reducing emissions include the Renewable Energy Target (a portfolio standard with tradable certificates) and the Emissions Reductions Fund (a government funded scheme to subsidize agreed actions to reduce emissions). Neither of these results in incentives for emissions intensive power plants to close. Yet Australia has an emissions target in place of a 26%-28% reduction in emissions from 2005 to 2030. To be on track to meet this target through domestic reductions would require comprehensive changes, and would likely include the cessation of using brown coal for electricity generation (Denis et al., 2014).

In the absence of an effective carbon pricing signal, closure by one or more plants could be achieved through direct regulation. However in light of recent experience with the political economy of climate policy in Australia it appears unlikely that a government would choose a pure regulatory approach that singles out power stations and imposes the full cost of early closure on the owners of that station. The alternative of government payments for closure suffers from the downsides laid out above and would involve undesirable on-budget transfers.

In this paper, we investigate options for policy approaches that overcome the difficulties of direct regulation and government subsidies for closure. We propose a market mechanism for regulated closure of highly emissions intensive power stations. The scheme would use a market mechanism to identify the most cost effective plant to close down and source the payments from the remaining power stations. This would be done in a way that would provide further incentives for reducing emissions by the remaining power plant fleet. We argue that such a regulated market mechanisms could solve the political difficulties and problems of information asymmetry that plague government payments for closure and direct regulation for exit respectively. We provide empirical illustrations that suggest that the closure costs are lower than the likely societal benefits of closure.

We intend this paper as a starting point for further research and to inform policy considerations. The paper also provides an overarching contribution to the literature on policy mechanisms for transition of electricity generation infrastructure.

Section 2 establishes the rationale and proposes a market mechanism for regulated plant closure designed to achieve plant exit that takes into account carbon emissions. Section 3 contains empirical illustrations. Section 4 concludes.

2. A market mechanism for regulated plant closure

If the case for policy intervention to close one of Victoria's brown coal fired generators as laid out above is accepted, then the question is which policy mechanism to apply. Three in-principle approaches exist (Nelson et al., 2015): government funding (or subsidies) for plant closures, a market-based solution, or direct regulation.

Here we describe an approach that is a hybrid of direct regulation and market mechanisms.

The argument against payments for closure

As shown in Section 3, it is reasonable to expect significant emissions savings in the NEM as a result of closure of one of Victoria's large brown coal fired plants.

In principle such payments for closure could be accommodated under the Emissions Reductions Fund (ERF). However there are strong arguments against payments for closure, whether under the ERF or under a separate arrangement.

Firstly, as Riesz et al. (2013) have pointed out, payments-for-closure schemes can lead to unhealthy expectations of future industry subsidies from government and therefore a deferral of plant closure decisions with associated emissions.

Secondly, the politics of paying significant sums of taxpayers' money to the owners of old, highly emissions intensive power stations would be highly problematic. It also does not fit the narrative of the present Emissions Reduction Fund (ERF) mechanisms, which is one of subsidizing businesses taking positive actions to move to cleaner production processes, not of compensation payments to sunset industries.

Objectives and constraints for a mechanism for plant closure

Given the premise that there is a case for policy intervention for plant closure in order to reduce greenhouse gas emissions, some objectives and constraints for a policy mechanism can be identified.

- Closing highly emissions intensive plants.
  To achieve maximum system-wide emissions savings, the closure scheme should apply to large highly emissions intensive plants. In the case of Australia's NEM, four brown coal fired generators in Victoria are considerably more emissions intensive than other power stations, and produce large amounts of electricity.
- Minimizing cost of emissions savings.
  If the primary objective is to achieve emissions reductions, the plant(s) with the lowest foregone expected future profits per unit of expected emissions savings from closure should shut down.
- Overcoming information asymmetries.
  The owners of generation assets have an informational advantage over the regulator regarding the cost of operating their plant, and hence expected future profits from continued operation. Government is therefore at a disadvantage in any negotiation with individual power station owners. Government may not be in a position to identify the most cost effective closure option. For example, the oldest or most emissions intensive plant may not always be the best plant to close first. A competitive bidding system as discussed here may overcome these difficulties and allow an optimal choice of plant for closure.
- No government subsidies.
  As laid out above, there are strong arguments against government payments for plant closure.
- Harnessing revenue gains to plants that remain in operation.

Table 1
The four large brown coal generators in Victoria.

	Hazelwood	Loy Yang A	Loy Yang B	Yallourn
Owner (Nov 2015)[a]	GDF Suez	AGL	GDF Suez	Energy Australia
Year commissioned[a]	1964–1971	1984–1988	1993–1996	1974–1982
Capacity, MW[b]	1760	2295	1200	1585
Capacity utilization rate, 2014 (%)[b]	70.8	80.0	71.5	77.1
Electricity dispatched, 2014 (GWh)[b]	9819	14,630	6952	9749
CO2 emissions, 2014 (kt)[b]	14,944	17,702	8606	13,814
Emissions intensity, 2014 (tCO2/MWh dispatched)[b]	1.52	1.21	1.24	1.42

Notes:.
[a] Sourced from the respective company websites: Hazelwood—GDF Suez (2015a); Loy Yang A—AGL (2015); Loy Yang B—GDF Suez (2015b); Yallourn—Energy Australia (2015).
[b] The third party software NEMSight from Creative Analytics was used to extract the relevant AEMO data (Creative Analytics, 2015).

If a large generating plant closes, this can be of some financial benefit to the plants that remain on the grid, because at the margin it will mean higher capacity utilization rates and also marginally higher electricity prices in the spot market. The nature and extent of the likely effects would need to be assessed in detail. Complications include that, given overcapacity in the market as it stands, the closure of a brown coal fired generator may allow a (black coal) generator that may otherwise have exited to remain in operation. Nonetheless, if the marginal cost of operation is higher for the plant that would otherwise have exited, some uplift in spot market prices during particular periods of time could occur. Also, some price uplift can be expected if payments for closure are covered through an output-dependent charge on operating plants, as proposed in this paper.

- Providing incentives to reduce emissions on the grid.

  A mechanism for plant closure also provides the opportunity to set incentives to the remaining plants to adjust operations in a way that saves emissions.
- Providing structural assistance to workers and regions.

  Closure of power stations and mines means job losses, which are typically concentrated in relatively small regional communities. Unmitigated, these localized economic and social effects can be a significant political hurdle to regulated closure. Closure should be accompanied by programs to facilitate retraining and resettlement of workers, and structural assistance to affected towns. Furthermore it needs to be assured that the sites of power stations and associated mines are remediated to make the land available for other uses, and to a standard acceptable to the community.

Outline of a market mechanism for regulated closure

On the basis of the objectives and constraints laid out above, we propose a market mechanism for regulated power plant closure.

The principle of the proposed mechanism is that government offer power plants the opportunity to bid for the closure of some amount of capacity, leaving it to the bidding process to determine which plant(s) will close and what the magnitude of the payment to the closing plant is. The remaining plants are then mandated by government to make financial transfers to the plant that exits the market, in line with their emissions.

Such a mechanism would: provide emissions savings from plant closure at least cost; rely on a market mechanism to identify which plant should close and what magnitude payment is required; avoid budgetary costs by sourcing the payments for closure from the plants remaining in production; and provide some incentives to adjust the power mix to reduce emissions.

Identifying which plant to close through competitive bidding

The closure of a given amount of high-emissions generating capacity in practice would mean closure of one or more brown coal fired generators in the state of Victoria. There are four main plants. They range in capacity between 1.2GW and 2.3GW, and in 2014 had emissions factors of between 1.21 to 1.52 tCO2/MWh. By contrast, average emissions intensity over the same period for the average black coal plant in the NEM was 0.91 tCO2/MWh (NEMSight used to access AEMO data, Creative Analytics, 2015) (Table 1).

The difficulty for a regulator would be how to identify which plant should close in order to minimize the cost of achieving emissions reductions. And even having identified a prospective plant, a regulator would have difficulties establishing how much to pay because of a lack of information about cost structures.

The information asymmetry between businesses and government can however be overcome through a competitive bidding mechanism. Specifically, the power plants in question – in our example the four large Victorian brown coal generators – would be invited to each submit a bid for the amount of money they would be willing to accept in return for closure. 'Closure' would be defined as ceasing operation on a predetermined date, remediating the site to a predetermined standard, and paying for a predetermined assistance package for their workforce and the regional towns they operate in. The bids could be provided in a sealed-bid auction.

The estimation of emissions savings would rely on analysis and modelling by a public agency—either a statutory authority or a government department. They would be estimated for the closure of each of the four plants separately, taking into account the likely substitution effects within the NEM (see Section 3), the likely period for which the plant would remain operational if it did not exit under the scheme, and other relevant factors. The results from this analysis would be made publicly available before the bidding process, so that companies have full information about the basis for evaluation by the regulator.

Once the bids are received, the regulator computes the cost of estimated emissions savings (in dollars of requested payment for closure divided by tonnes of estimated CO2 savings), and chooses the most cost-effective bid(s).

The regulator's decision could also factor in other aspects of public benefit from closure, such as reduced local air pollution (e.g. particulates and heavy metals), and local amenity benefits. This would be best done with full transparency so that plant owners would know the basis for evaluation in advance. In this paper we set aside non-carbon benefits.

Bidding strategies and regulatory responses

The brown coal generators bidding for closure would estimate their future expected profits under different scenarios of power station closures. The optimal basis for their analysis would be to estimate the expected future profits of all four plants under the scenarios for exit by each one of them. Each plant owner would then submit a bid that leaves it better off than estimated under the alternative where its own bid is not accepted.

In this analysis, each business would use its own best estimate of its own profits and costs and those of its competitors, combined with the information (publicly provided by the regulator) about estimated impacts on emissions in the case of closure of each of the four plants. Companies typically own a number of different generators in the NEM. As a result, the financial scenario analysis – and hence the bids for closure – would also include changes in revenue and profitability (typically increases) and required contribution to the closure payment by other generators owned by a company that owns brown coal generators.

There would be incentives to submit high bids to maximize revenue in case of closure, but also countervailing competitive pressure to submit low bids in order to be selected for closure payments. By definition, having its bid accepted and closing down would leave the plant better off than remaining in operation. Inflating the bid increases the financial advantage if the bid is successful, but at the same time it diminishes the chances of the bid being successful.

Bids could be higher than the estimated foregone profits for two reasons. Firstly, the plant that considers itself to be the lowest cost option for closure – and which would thus expect to be able to submit the lowest bid – may choose to submit a bid that is below the closure costs of its presumed next highest bidder, but above its own closure costs. This is a common outcome in auctions.

Secondly, the small number of bidders (noting that two of the four plants are owned by the same company) could give rise to strategic interactions or non-competitive bidding.

Aspects of strategic behaviour would require detailed investigation by the regulator, and may require the design of the auction to be customized.

The regulator would choose the bid that offers the lowest ratio of closure payment to estimated emissions saved (in $/tCO2). Other aspects of each bid could also be factored into the decision.

It would also be possible for the regulator to reserve the right not to award a closure contract if it deemed the most cost effective bid too high relative to the public benefit.

Payment by the remaining generators in line with future emissions

The exiting generator would receive the full amount specified in their bid, in instalments over a pre-determined timeframe (here we assume over one year). The financing for this payment would be shared among the generators that remain in operation.

A multitude of options exists for apportioning shares of the payment to be made by the remaining generators, with different effects on distribution and incentives.

Given that all remaining generators would benefit from some price uplift in the NEM, one option would be for contributions to be shared among all remaining generators, according to their electricity output during the year (or other period) following the closure of the chosen brown coal fired plant. However this could be seen to disadvantage the renewables and gas fired power sector, because one or more black coal fired power plants (instead of the brown coal plant) might have exited the market anyway, with associated marginal increases in spot market prices but no payments to be made by other generators.

Another option would be to share contributions among all remaining plants according to their carbon dioxide emissions during the year (or shorter/longer period) following the closure of the chosen plant. We consider this option as preferable, pending further analysis, and use this scenario for illustration below.

We identify three key properties of this scheme.

First, the benefits to generators from staying in the market would be offset in proportion to their emissions intensity, counteracting any incentives to remain in the market in the expectation that there might be further rounds of payments for closure (as highlighted by Riesz et al. (2013) as a main disadvantage of a payment for closure policy).

Second, payments in proportion to emissions following the closure of one plant provide an additional incentive for all brown-coal fired generators to submit low bids in the closure scheme, as the benefits from staying operational are diminished.

Third, an incentive effect within the NEM for a marginal shift towards lower-carbon generators would be provided, as the closure payment would effectively be financed through a levy on future carbon dioxide emissions. As indicated by the numerical illustrations below, this effect is, however, likely to be very small.

Price uplift and cost incidence

The ultimate cost incidence would largely be on electricity consumers, through higher prices in the NEM and potentially higher prices in negotiated electricity supply contracts. The precise extent and nature of cost pass-through is a matter for fine-grained empirical modelling. Factors that would affect spot market prices, with a likely uplift of prices in net terms, include the following:

- Changes to marginal cost structure in the bid stack given retirement of a lower marginal cost generator (brown coal) instead of exit by a higher cost one (likely black coal), given the lack of a carbon price signal under current policy settings.
- Changes to marginal operating costs associated with payment on the basis of emissions by remaining plants may lead to higher spot market prices during some periods.
- Effects of full decommissioning of plant rather than mothballing (see Nelson et al. (2015)) on investment in new plants especially renewables, and associated impacts on wholesale prices.
- Any time discrepancy of retirement associated with the policy. If the policy induces a brown coal plant closure ahead of when it might have happened to a black coal plant without intervention, there would be a period of higher price uplift associated with reduced capacity over that period. Conversely, if the policy takes longer to take effect than it would have taken for a black coal plant closure to take place, then the additional capacity for that time period would depress prices for longer. This highlights the importance of moving quickly from announcement to implementation of any such policy.

In principle the gains to generators in higher profits (given uplift) could be higher or lower than the required payment for exit to achieve the closure of one of the large brown coal plants. Only detailed modelling will provide a reliable net estimate of the effects at play, especially in relation to any displacement of capacity that would have been retired in the counterfactual case. What is clear is that the negative effect on generator profits will be (weakly) related to their emissions, providing little if any incentive for generators to hold out for further rounds of this policy to receive payment for closure, especially given the additional costs associated with any exemplary exit conditions.

The (small) electricity price impact, especially on low-income households, could in principle be offset by targeted transfers, changes in electricity tariffs or by supporting investments in energy efficiency. However as illustrated in Section 3, the cost impacts would likely be very small, and compensatory measures may not be considered necessary. The electricity price increase would also affect business, though again the magnitudes would likely be very small.

Structural adjustment and site remediation

The regulator would set out in detail the requirements for an assistance package for affected workers and local communities, as well as for site remediation. Plant owners would take this into account in their bids. In effect the cost of assistance and site remediation would become a component of the overall bid, and thus a component of the payment made to the successful bidder. The overall cost of the package would vary between the plants, depending on size and circumstances.

Dynamic aspects

After an initial round of regulated closure there could be further rounds in the future. The prospect of these occurring would affect the estimation of all plants' future revenue, and thus the bids in the first round. However, if contributions are shared on the basis of emissions intensity, this will reduce the effect of expected future rounds on the brown coal plants.

Plants will consequently factor their own expectations about future regulated closure into their bids. Given the adverse effect that policy uncertainty has on energy sector investors (Jotzo et al., 2012), it would be desirable for the regulator to announce the full intended schedule of future rounds of regulated closure at the outset.

Finally, it must be recognized that a government's announcement of intent to implement a closure policy could provide incentives for plants to remain in operation that might otherwise have closed down without intervention.[2] Therefore governments should move swiftly from consultation to announcement to implementation.

3. Empirical illustrations

Here we provide some empirical illustrations of the possible effects of the closure of one of Victoria's large brown coal fired power stations, in the context of the mechanism proposed in Section 2.

2 For example, the Northern and Playford power stations in South Australia are expected to close in 2016 (Alinta Energy, 2015) without payments for closure or other policy intervention, while it is understood that they were part of discussions in the earlier aborted federal government 'payment for closure' scheme.

Estimating emissions savings from plant closure

One key determinant of the emissions savings to be expected is the extent to which closing down a brown coal generator displaces the closure of other plants. Indeed, assuming that the analysis by AEMO (2015) that there is overcapacity is correct, and the assessment by the AEMC (2015) and others (e.g. Riesz et al., 2013) that plant exit is occurring in response to such overcapacity is also correct, then regulated closure of a brown coal plant will essentially displace the closure of other plants.

This does not negate the benefits to intervention sought here, namely to achieve exit outcomes that are consistent with the public interest given the lack of carbon price signals in the NEM at present. Indeed, the intention of the scheme is to address the problem that the relative profitability of emissions intensive plants is inflated compared to lower emissions plants, given lack of carbon price signals. Without intervention, lower emissions plant (black coal) might be retired while higher emissions plants (brown coal) remain in the market, with adverse effects on the emissions intensity of overall power supply. With a carbon price in place, the reverse can be true depending on the price level.

To have confidence in calculated emissions savings from closing a specific power plant, a comprehensive modelling exercise would need to be undertaken, taking into account the complexity of the electricity market including electricity supply, bids and prices at short time intervals, and comparing the policy scenarios with counterfactuals.

Here we provide some bounding calculations, which can be used to illustrate the magnitude of emissions savings available.

Assuming that the exit of a brown coal generator simply offsets the retirement of a black coal generator, emissions savings would be a function of the difference between black and brown coal emissions per MWh generated and any changes to the generation mix.

As an illustrative example, if one of the higher emissions brown coal plants (Hazelwood or Yallourn) were to exit, and using generation figures for 2014, avoided generation would amount to about 9.7 TWh per year with associated emissions of about 14 to 15 $MtCO_2$. Equivalent black coal generation, on the black coal fleet average emissions coefficient, would give rise to about 9 $MtCO_2$ per year. Thus the first-round emissions saving from closing high emissions brown coal rather than the black coal plant(s) would be about 5 to 6 $MtCO_2$ per year.

There are a number of second-order effects to consider here.

Most importantly, there could be increases in generation by other brown coal plants. However, initial analysis suggests that such 'leakage' is not likely to be large, because brown coal plants generally operate at fairly high utilization rates. Indeed, if we assume the remaining three brown coal plants increase their generation to the highest annual average observed over the past decade (83.5% for Hazelwood, 88.3% for Loy Yang A, 86.5 for Loy Yang B and 88.6% for Yallourn), this would soak up only a share of the reduced output, whichever plant exits.

Other second-order effects would tend to decrease the emissions intensity of overall electricity generation further. Firstly, in principle some of the displaced brown coal generation could be made up for by gas-generated power, though this may not be the case in practice to any significant extent in Australia because gas is relatively expensive and in short supply (Simshauser and Nelson, 2015). In addition, one could expect some renewable energy investment to be brought forward. Further, any increases in electricity prices could result in reductions in end use, although these effects are likely to be small indeed.

Table 2 illustrates potential emissions savings from the closure of each of the four large brown coal plants, assuming a more moderate (and pending detailed modelling perhaps more realistic) leakage rate of 30% to the remaining brown coal plants.

Illustrative valuations and costs

Valuation of carbon dioxide emissions reductions

The above indicative calculations suggest emissions savings for the closure of one of the more emissions intensive of Victoria's brown coal fired power plants of around 2 to 6 million tonnes of carbon dioxide per year. A comprehensive, modelling based analysis may give different results.

Different valuations can be applied to this estimate. A benchmark for the government's willingness to pay for emissions reductions are the prices paid by government for contracts for emissions reductions under Australia's first auction of the Emissions Reductions Fund (ERF). The average price under the first two ERF auctions was $13.12/tCO2-equivalent (Clean Energy Regulator, 2015). The price level may change in subsequent rounds. Further, there are also the costs of raising public revenue through the tax system to consider. Estimates for the marginal excess burden of taxation vary (see Cao et al., 2015), but as an illustration we use 30%. This implies an effective average cost to taxpayers of around $17/tCO2-equivalent under the ERF.[3]

An alternative basis for valuation is the social cost of carbon, which is a measure of the discounted value of expected future global damages from additional GHG emissions—the global value of reducing emissions. There is a large literature on estimates of the SCC, showing a very wide range of estimates (Tol, 2011). A set of estimates exists that has been widely used

[3] On the (quite possibly optimistic) assumption that contracted emissions reductions are 'additional' – that is they would not have happened otherwise – and ignoring likely future increases in average ERF contract prices.

Table 2
Scenarios for emissions savings from plant closure.

	Withdrawn brown coal	Additional black coal if all gen made up by black coal	Additional brown coal if remaining brown coal plants soak up 30%	Additional black coal if remaining 70% made up by black coal
Retire Loy Yang B				
Generation (GWh sent out)	−6952	6952	2085	4866
Emissions factor (tCO2/MWh)	1.24	0.92	1.36	0.92
Emissions (MtCO2)	−8.61	6.40	2.83	4.48
Emissions savings (MtCO2)		**−2.21**	**−1.30**	
Retire Yallourn				
Generation (GWh sent out)	−9749	9749	2925	6824
Emissions factor (tCO2/MWh)	1.42	0.92	1.31	0.92
Emissions (MtCO2)	−13.84	8.97	3.84	6.28
Emissions savings (MtCO2)		**−4.87**	**−3.72**	
Retire Hazelwood				
Generation (GWh sent out)	−9819	9819	2946	6873
Emissions factor (tCO2/MWh)	1.52	0.92	1.28	0.92
Emissions (MtCO2)	−14.94	9.03	3.77	6.32
Emissions savings (MtCO2)		**−5.91**	**−4.85**	
Retire Loy Yang A				
Generation (GWh sent out)	−14,630	14,630	4389	10,241
Emissions factor (tCO2/MWh)	1.21	0.92	1.41	0.92
Emissions (MtCO2)	−17.70	13.46	6.18	9.42
Emissions savings (MtCO2)		**−4.24**	**−2.10**	

in public policy analysis, developed by the US Interagency Group (2010, 2013) as a basis for regulatory analysis in the United States (see also Greenstone et al., 2011 and Johnson and Hope, 2012). These estimates have the SCC at A$88, A$57 and A$17 respectively for discount rates of 2.5%pa, 3%pa and 5%pa, and at A$166 for a scenario of high climate change damages.[4] On the basis of the literature on discounting for climate change analysis (Edenhofer et al., 2014), a 5% discount rate is considered outside of the applicable range.

Thus, an illustrative range for the evaluation of the carbon benefits from plant closure is $17 to $88 per tonne of carbon dioxide. Benefits from reductions in non-CO_2 air pollution would also likely accrue (ATSE, 2009; Ward and Power, 2015) but are set aside in this example.

The illustrative range of potential emissions savings from the closure of the two older brown coal plants provided above is 4 to 6 MtCO2 per year. Assuming the annual savings are maintained for between 5 and 15 years (on the basis that this is the period until closure of the brown coal fired plant would happen anyway), this yields a range of 20 to 90 MtCO2 in total. Evaluated at $17/tCO2 and $88/tCO2, this yields a range of $340 million to $8 billion in total monetized benefits for carbon dioxide savings.

It appears likely that the emissions benefits from brown coal plant closure as evaluated here are larger, and possibly much larger, than the likely additional power system costs and bids under a market mechanism for regulated closure.

Closure costs

We do not have information available about the payments that would be required to facilitate closure of the relevant power plants, in particular of the magnitude of foregone profits as a result of early closure of brown coal fired power plants.

Site remediation costs are thought to be in the order of $100 to $300 million (Nelson et al., 2015, p26). The cost of a structural assistance package is unknown, however as an indication, the Hazelwood station employs 540 workers directly and around 300 contractors, and more during periods of maintenance. An illustrative package of $150 million would then provide over $100,000 per worker/contractor, and another $50 million to the community.

It is important to note that remediation and retrenchments costs would have to be borne by the plant owners in any case at a point in the future when closure will inevitably occur. Additional costs from a regulated closure scheme would consist only of any additional impositions on the business over and above their existing commitments, for example payments for community assistance, worker re-training over and above retrenchment packages, or site rehabilitation to a higher standard than would otherwise occur.

Cost ratios

To illustrate the financial effects on the industry, we assume a one-off payment for closure of between $400 million to $1billion, shared between the remaining power generators.

4 For assessment of emissions in 2015, using an exchange rate of A$0.74/US$, with inflation adjustment from the 2014 base on the estimates.

Total CO2 emissions from electricity generation during 2014 were 153Mt (Creative Analytics, 2015). Under a scheme where closure payments are covered by generators in proportion to their CO2 emissions, a $400 million or $1 billion total payment implies a CO2 levy of $3/tCO2 to $7/tCO2 if the full payment were covered over the space of one year. This is only a marginal impact on relative costs based on emissions intensity, however at certain times it would change the merit order in the NEM, and consequently it would lead to marginal re-adjustments in the fuel and plant mix, and lower overall CO2 emissions.

Based on the 2014 generation mix in the NEM and CO2 emissions by technology, 54% of the total payment would be covered by black coal plants, 38% by brown coal plants, and 8% by gas fired plants. These shares would be adjusted for the reduction in brown coal fired generation.

Total electricity sent out in the NEM during 2014 was 182 Twh (Creative Analytics, 2015). So the illustrative payments would amount to around $2/Mwh to $5/Mwh. This compares to typical NEM wholesale prices over longer term periods of around $40/Mwh. Assuming that the closure payment would be fully reflected in higher wholesale prices as an upper bound, this would amount to an increase of 5% to 14% in wholesale prices over the course of one year (and prices dropping again afterwards). The corresponding increase in retail prices would only be in the order of 1% to 2%, over one year (assuming retail prices of 25c/kwh and full cost pass-through from wholesale to retail prices).

4. Conclusions

Australia has overcapacity in electricity generation that includes a number of highly emissions intensive brown coal fired plants, a renewable energy target mechanism which brings new capacity into the grid, but no carbon price signal. In this situation, it is possible that black coal generators will be closed down ahead of more polluting brown coal generators, because running costs of brown coal plants are lower.

This would mean missing out on opportunities to reduce emissions, and realizing other societal benefits from closing old brown coal fired plants. The likely emissions benefits from brown coal plant closure could be of much higher social value than the additional power system costs. Our empirical illustrations suggest that system-wide emissions reductions from closure of one of Australia's four largest brown coal fired power stations could be between 1.3 and 6 MtCO2 per year, and 4 to 6 MtCO2 per year for one of the two most emissions intensive plants, depending on assumptions about which plant is closed and which generators would make up for their output.

Valuing these reductions either at the price paid for contracted emissions reductions under Australia's Emissions Reductions fund or at the social cost of carbon suggest that the value to society may well exceed the payments required for closure, even before considering non-carbon benefits; and a large part of the payments would not represent additional costs compared to those resulting from alternative closure of a black coal fired power station.

Given that Australia has a target to reduce national emissions and the government is not planning to re-introduce a comprehensive carbon price, this would suggest that specific government intervention to close brown coal capacity is warranted in principle. However, the policy mechanisms usually suggested to induce such plant exit have substantial drawbacks. Direct regulation suffers from government not having sufficient information about business cost structures, and therefore it would be difficult for the regulator to identify which plant would be the most cost-effective to close and how much to offer in compensation if such compensation was offered. Moreover, a scheme of government payments for closure suffers from lack of political acceptability.

In this paper we have proposed a market mechanism for regulated power plant closure that would overcome these difficulties. It could achieve a closure of the plant(s) that would reduce emissions most cost effectively, and meet a number of constraints.

The principle of the proposed mechanism is that government mandates the closure of some amount of capacity by way of regulation, but leaves it to a competitive bidding process to determine which plant(s) will close and what the magnitude of the payment to the closing plant is. The plants remaining in operation then make financial transfers to the plant that exits, in line with their emissions during a period following closure of the selected plant.

Such a mechanism can provide emissions savings from plant closure at least cost, avoid budgetary costs by sourcing the payments for closure from the plants remaining in production, and provide some incentives to adjust the power mix to reduce emissions. In addition, payment by remaining generators on the basis of emissions helps overcome adverse incentive effects that might otherwise be present for plants to stay in operation in anticipation of payment for closure.

While any additional costs compared to a scenario where black coal plants exit would ultimately be borne by electricity consumers, the impost would be small and temporary.

With this paper we hope to re-kindle a discussion in Australia about government facilitating efficient exit of highly polluting power stations, an outcome that may otherwise not be achieved in the absence of carbon pricing. The proposed mechanism may also be applicable in other countries, in particular developed countries with over-capacity in older coal fired power plants. And while we have described the mechanism for the specific situation of exit of brown coal fired power plants, it could apply to any situation where exit of relatively high emitting plants is socially desirable.

Many aspects of power station exit and the specific mechanism proposed will require further analysis. Among them are strategic behaviour in a market with a very small number of candidate plants and cross-ownership of plants and effects on the bids that would be made under a closure scheme. Also needed will be detailed modelling of likely emissions savings from brown coal emissions plants, taking into account merit order and plant availability at a temporally and spatially disaggregated level, that is taking into account load curves and interconnector capacities between State grids. Modelling of the effects of brown coal plant closure on spot market prices, especially whether and to what extent there would be price uplift and associated revenue in wholesale electricity markets will also be required.

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