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Is there a more effective way to reduce carbon emissions?

AN ALTERNATIVE TO EMISSIONS TRADING AND CARBON TAXATION

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Abstract

Whilst emissions trading systems are widely held to be able to deliver lowest-cost abatement, uncertainty reduces their effectiveness. We consider a new scheme, the Tender-Price Allocation Mechanism, which focuses carbon factor cost expenditure on abatement rather than just revenue transfers. It is a scheme that reduces uncertainty and the costs of uncertainty for both firms and regulators. It also incorporates a suite of incentives that compensates for the externalities associated with abatement investment.

Section 1 Introduction

In Australia and internationally, we have witnessed intense discussions concerning the best policy to reduce greenhouse gas emissions. The two main proposals are a carbon tax (CT) and an emissions trading system (ETS). The latter is favoured over the former mainly because, first, it can set a reduction target and, second, because increasing taxation is never palatable politically. The debate concerning the relative merits of these policies has tended to crowd out discussions about alternative schemes. This is surprising because both policies have potential problems, both in implementation and in achieving their goals. The ETS is a 'quota' policy which deviates from economists' preference for 'tariff' schemes, particularly in the context of international trade. Also, since both are 'stick' rather than 'carrot' policies that raise prices that are passed on to consumers, they depend upon there being a high enough price elasticity of demand to achieve significant reductions in demand. If demand is price inelastic then little will be achieved without very high increases in a carbon price with serious consequences for low income consumers. In particular, neither scheme addresses the consequences of increased cost or decreased emission reduction as a result of uncertainty.

A long time ago, Martin Weitzman (Weitzman, 1978) argued that, in states of uncertainty, it is necessary to have policies that involve both price and quantity mechanisms: "…*far from being a contradiction, is actually optimal in a world of uncertainty"* (Weitzman, 1978, p688). Weitzman pointed to policies to control pollution as a clear case in point. Instead of pursuing Weitzman's findings, we have had an 'either-or' debate, with the ETS supported by proponents of free markets and small government and the CT by those who expect government to direct private enterprise through the introduction of regulatory systems that include both corrective incentives and penalties. Often overlooked by the pro-market lobby, but stressed by the late Arthur Okun in his book *Prices and Quantities* (Okun, 1981), and echoed by Joseph Stigitz (Stiglitz, 2002), we are never dealing with an economy guided by the 'invisible hand' but one where there is a necessary 'invisible handshake' between interacting parties in the economy, including those between the private and public sectors. What this handshake involves is the active participation of government in the establishment of regulatory arrangements that facilitate economic activity that otherwise wouldn't be possible and, in so doing, allowing private sector agents to take advantage of new, innovative opportunities.

So, Weitzman has provided a convincing argument that a hybrid price/quantity scheme is necessary to curb atmospheric pollution. Currently, one exists, proposed by McKibbin and Wilcoxen (MW) (McKibbin and Wilcoxen, 2002), so it is worth discussing its advantages and disadvantages before moving on to our proposal. The MW proposal involves the allocation of long-term emission permits to specified thresholds, plus annual permits, sold to reduce the costs associated with excessive permit demand. The mechanism aims at a quantity target but is overlaid with a price mechanism as a 'safety valve'. The requirement for long-term permits to emit is based on the premise that there is no damage from emissions until certain thresholds are breached, and that permits to emit should be allocated up to the level of what is assumed to be an allowable threshold. Only emissions over and above the allowable threshold are then penalized to bring emissions back to the threshold. Whilst different ways of allocating the long-term permits are identified, their preferred method is to allocate free 'grandfathered' permits. This is designed to garner political and industrial support for the scheme and avoids large revenue transfers to government (McKibbin and Wilcoxen, 2002).

The MW mechanism is prompted by a need to minimize costs, but it has a number of aspects that will cause it to be unsuccessful. The first relates to the international allocation of the long-term permits to owners with vested property-rights. Any reduction in quantity targets would require a buy-back of these long-term permits, which could come at a substantial social cost.[1] The second aspect is the assumption that damages will only happen over an allowable threshold. It is illogical to place no or little cost on the millions of tons that are emitted prior to a threshold-breach in a world where carbon dioxide concentration is rising. Also, since there is a great deal of uncertainty around the allowable threshold, this uncertainty increases risk and therefore the cost of valuable property rights. The final aspect is the preference for an allocation of free permits. Evidence from the EU ETS and the US SO_x programs is that free emission allocations do not drive investments in new abatement technologies in any significant way (Carlson et al., 2000, Grubb and Neuhoff, 2006).

Underlying the MW model is a concern that the science underpinning the effects of CO_2 emissions is still uncertain and contestable, implying that it would be costly to act prematurely. It focuses on a business-as-usual approach until the climate science becomes clearer, when the required action can be determined. Experience from the EU ETS implementation shows, however, that basing allocations on business-as-usual emissions leads to inflated emission projections, windfall profits for polluters and limited abatement (Grubb and Neuhoff, 2006). So, although there is merit in the MW hybrid proposal its cautious approach to climate change and generosity to polluters suggests that its capacity to reduce emissions significantly in the coming decade is questionable. In particular, it does not involve strong incentives for firms to invest in abatement technologies in the near term. We argue that, without such incentives, reaching even modest abatement targets will be very difficult.

The *Tender-Price Allocation Mechanism* (TPAM) proposal that we offer here is much more ambitious and has a range of attractive features. It is a scheme where the government appoints an independent regulator to manage an incentive structure that has both price and quantity effects. But, instead of letting a market or a policy determine a carbon price, it is determined

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[1] Australian buy-back of water rights in the Murray Darling Basin is proving very costly.

by a rule, providing certainty in the private sector and reducing the need for an army of expensive traders and advisors in a new speculative market. In other words, in our scheme, a regulator sets price and the private sector tenders quantity. The scheme is designed to be neutral - polluters fund investors in pollution mitigation - and is entirely fenced off from the fiscal position of government so that there is no capacity to do a carbon ‘tax grab’ to finance other deficits, as recently suggested by Nordhaus for the US (Nordhaus, 2010). Importantly, our calculations suggest that the impact of the scheme on electricity costs would be to increase the average electricity generation cost by a modest 2.7c/kWh and that the incentive for power generators to shift technologies is strong.

Significantly, any charge levied on carbon emissions is treated as a *factor cost* not as a tax. Thus, investments to mitigate emissions are treated like any other innovative investment to reduce factor cost. However, because investors in abatement technology are faced with uncertainty, not quantifiable risk, we know that they won’t apply standard discounting techniques. In such circumstances, there are two drivers of investment behaviour: strategic considerations and the quality of information. The former relates to first mover advantages and early demonstrations of commitment to potential competitors. The latter relates to the quality of information relating to the expected profitability of the investment that is available. The first is about making brave entrepreneurial decisions and the second is about conservatively deferring them.

It is well known that the unit costs associated with new technologies fall over time as scale of application increases and incremental innovations occur. However, what is not known is how much these costs will fall and how long this will take. So, for example, it may pay to wait to invest in solar technology following the reasoning of Dixit and Pindyck (1994). The problem with this is that uncertainty leads to under-investment and a distributional shift away from those brave (or foolhardy) enough to invest when costs are high to those who enjoy lower costs later. In such circumstances, incentives are necessary that compensate early investors for the unusually high risks that they take and this compensation should come from those deferring risk and, in this case continuing to pollute.

Of course, patents and copyrights are designed to advantage early investors in new technologies but these rarely protect an entrepreneur who is bringing technologies together within novel organisational structures. Furthermore, there are usually pressures brought to bear by owners of existing technologies, who face 'creative destruction,' seeking compensation for impending losses. This adds to the uncertainty faced by entrepreneurs trying to kick start a new technology. The problem with both an ETS and a CT is that they both impose a greater cost in the short- and medium-term on the firms that are investing in carbon abatement than on those who are doing nothing. Indeed, latter can enjoy free permits in some ETS proposals and still not actively pursue abatement.

Now, it may still be true that a carbon price triggers an investment, but this may not result in lowest-cost abatement. An ETS triggers uncertainty about the cost of permits[2], a CT involves uncertainty about the cost of future policy and neither an ETS nor a CT address the uncertainty associated with the cost of research to transition to low-carbon technology[3]; but these uncertainties defer investment (Dixit and Pindyck, 1994) and drive up the cost of abatement. A focus on the property rights of pollution fails to reflect the social benefit of abatement. If firms can provide evidence of abatement investment which delivers a social

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[2] There is evidence of worst-case scenarios of uncertainty, eg the RECLAIM market for NOx emissions in Southern California resulted in uncontrollable permit price escalation KEOHANE, N. O. (2009) Cap and trade, rehabilitated: Using tradable permits to control U.S. greenhouse gases. *Review of Environmental Economics and Policy,* 3**,** 42-62., or the EU ETS carbon market resulted in uncontrollable permit price slide GRUBB, M. & NEUHOFF, K. (2006) *Emissions trading & competitiveness : allocations, incentives and industrial competitiveness under the EU emissions trading scheme,* London, Earthscan Publications.

[3] Montgomery finds that there is a "dynamic inconsistency" in incentives to invest in abatement for both a price and a quantity mechanism MONTGOMERY, W. D. & SMITH, A. E. (2005) Price, Quantity and Technology Strategies for Climate Change Policy. *CRA International..* Jaffe points to investment market failure which discourages investment in environmentally friendly technologies JAFFE, A. B., NEWELL, R. G. & STAVINS, R. N. (2005) A tale of two market failures: Technology and environmental policy. *Ecological Economics,* 54**,** 164-174.

benefit, there should be no penalties levelled at them in the form of emission permit purchases or carbon taxes. A carbon price should be levied only at those that do not invest to abate. This is what TPAM seeks to achieve. As we shall show, the benefits of TPAM are many, but can be summarized as: bringing abatement investment forward; reducing revenue transfers; reducing the cost outlay for firms; reducing knowledge investment by firms in an auction market; and dramatically reducing all the uncertainties, costs and opportunistic behaviour inherent in the auction mechanism.

The rest of the paper is organized as follows: Section 2 presents the details of the Tender-Price Allocation Mechanism, provides a detailed analysis of Marginal Abatement Costs and conducts a sensitivity analysis on some of the key variables. Section 3 analyses the effectiveness of TPAM, compares it to other mechanisms, provides evidence from the literature of the efficiency of combined tax-subsidy programs and discusses the possible shortcomings of the mechanism; Section 4 contains concluding remarks.

Section 2 The Tender-Price Allocation Mechanism (TPAM)

A carbon price (permit purchase or tax) is a payment for the use of a public resource. Thus, it is a factor cost. But buying a permit from someone who is 'under-polluting' is a zero sum game, environmentally. Government can restrict the quota of permits traded, thus, pushing up the price (or set a tax to reduce use) but this will only be effective if the higher price causes new investments in carbon abatement by polluters. This will only occur if polluters can pass on the carbon cost. If the ultimate consumer has a price inelastic demand, then a quota can only be attained at a very high carbon price, with serious effects on low income consumers.

The introduction of a carbon price through the Climate Change Levy (CCL) in the UK provided evidence of gaps between the predictions of economic theory and experience from the real world. The CCL should have encouraged 'rational' firms to pursue energy efficiency in response to a price signal, but firms' failed to act, requiring extra incentives to change their behaviour (House of Commons Environmental Audit Committee, 2008). Firms' focus on short-term profitability (Sennett, 2006, Murphy, 1985), average cost pricing (Lucas, 1999) and a "sunk cost bias"(Al-Najjar et al., 2005) exhibit behaviour which is not geared to investment with long pay-back periods. So observed real world behaviour suggests that a simple price signal is not enough to overcome disincentives to investment in abatement. Thus, there have to be significant incentives to encourage polluters to introduce carbon abating technologies if quotas are to be met at acceptable carbon (and electricity) prices.

The TPAM scheme involves an independent Regulator who estimates what the cost of meeting an abatement target would be (Control Cost), in the absence of private abatement, for a given period. This yields a Marginal Abatement Cost (MAC) which becomes the threshold against which the Regulator assesses tenders by firms to abate. The Carbon Price is the Regulator's estimated cost of abatement per tonne of emissions for the country. In order to tender, firms[4] are required to calculate their Carbon Cost, (i.e., the Carbon Price x projected emissions) and project the abatement that they can achieve by investing in carbon abatement technologies. Firms that are able to tender abatement at less than the threshold MAC are eligible for free permits to pollute. Those firms that are unable to meet the threshold level of abatement are required to purchase permits for all their emissions over the entire period.

2.1 The microeconomic principles of TPAM

Effectively the target, or quota, associated with a carbon price introduces a 'penalty' scheme. History is full of failed quota schemes administered by governments. High prices, induced by

[4] To avoid excessive transaction costs, only the major emitters could be covered, like the Carbon Pollution Reduction Scheme. This will increase the cost to firms as abatement will be required of a smaller country total. To reduce the cost impact it could be beneficial to include agriculture and land-use change as block groups.

quota schemes, have provided strong incentives to breach the quota through product differentiation, geographic relocation, illegal trading, falsification of records, etc. In the context of the 'invisible handshake,' quota rationing in peacetime has always been viewed as unfair expropriation by consumers and something to oppose and undermine. It is only acceptable if it is understood that the goal is to transfer revenue to solve a widely accepted social problem. So, rationing and high prices in wartime are accepted, not because they deter excessive consumption but because it is accepted that resources have to be transferred to the war effort. So, to be acceptable, a charge on carbon must be seen to have a *direct and visible* effect on investment in carbon abatement.

To understand how this works with TPAM, let us begin by looking at a typical firm's position. Consider a simple profit (π) function for a firm in the face of an ETS or a CT:

$$\pi = PQ - CQ - EiQ - \left(\frac{n}{z}\right)KA$$

Equation 1

Where

- *Q:* Quantity produced
- *P:* Price of quantity produced
- *C:* Cost of quantity produced
- *E:* Carbon Price (permit or tax)
- *i:* Emissions intensity of quantity produced(function of KA)
- *n:* Number of years in program
- *z:* Life expectancy of abatement technology
- *KA:* Cost of investment in abatement (function of E)

The hope is that the introduction of a carbon price (E) will cause the firm to increase investment KA and, in turn, this will decrease emission intensity *i,* which may, or may not decrease emissions depending on how much *Q* grows. Thus, there is a two way relationship, with the cost of investment, *KA,* influencing the cost of carbon, *EiQ,* and carbon price, *E,* influencing investment, *KA*. The firm clearly has two costs it has to bear, one compulsory *EiQ,* and another, *KA*, that is chosen. The sensitivity of KA to E will depend upon the ease with which the carbon cost can be passed on and, ultimately, the price sensitivity of consumers. So, it is a private choice as to how much KA will be and, thus, how much carbon is abated. In theory, the carbon price rises until it is high enough to generate the target amount of abatement. Unless the carbon price is high, it will not be worth the extra investment to abate, particularly in an uncertain environment where the logical thing to do is wait. But the problem is that, with pass-on and price inelasticity of demand, this could be a very high, and politically unacceptable, price.

Thus, there is a gap between a socially-optimal carbon price and a socially-acceptable carbon price. TPAM provides a formal mechanism to fund abatement in the presence of this gap, whereby a firm is relieved of all of its *EiQ* (Carbon Cost) liability if the abatement that it tenders to the Regulator, representing investment *KA,* delivers cost-effective abatement, such that the firm's profit function is reduced to:

$$\pi - PQ - CQ - EiQ$$

Equation 2

Requiring firms to tender competitively for free permits to emit assumes that the firms that are successful in proving their abatement potential would meet a minimum condition:

$$Carbon\ Cost = EiQ = \left(\frac{n}{z}\right)KA$$

Equation 3

Or looked at another way, where a firm can provide low-cost abatement, the cost associated with the public bad (Carbon Cost = -EiQ) is equated to the cost of the public good (carbon subsidy = +EiQ), as long as expenditure on abatement, $(\frac{n}{z})$KA, is maximized. If firms are unable to tender cost-effective abatement, the *EiQ* revenue received from those polluters can be channelled to firms as a subsidy for additional levels of efficient abatement. Figure 1 provides an illustration of Equation 3.

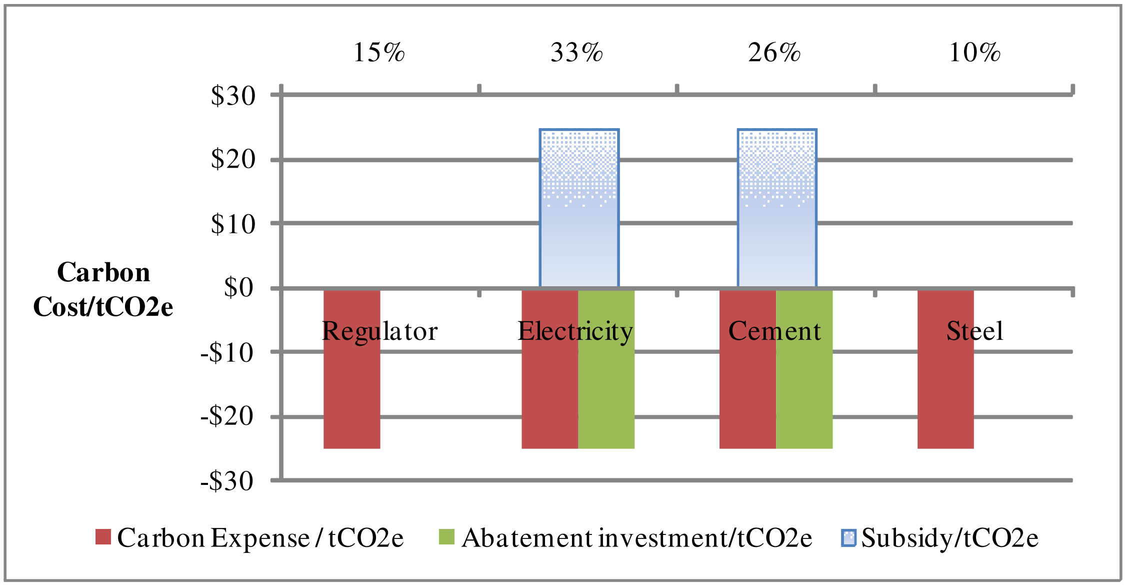

Figure 1: Cost of Carbon

At a $25 Carbon Price, the electricity generator tenders to provide 33% abatement, the cement manufacturer 26%, and the steel-maker 10% abatement. Where the abatement tendered is better than a Regulator threshold (in Figure 1, 15% abatement), the firm's Carbon Cost obligation could be applied, not to the purchase of permits, but to expenditure on abatement. In effect, the firm receives a subsidy because of the social benefits of its abatement strategy. The carbon subsidy will only apply to those firms offering lowest-cost abatement. In this example, the electricity generator and the cement manufacturer receive a $25/tCO2e carbon subsidy to cover $25/tCO2e of their abatement expenditure and the steel maker receives no subsidy, but can still pursue abatement if a private benefit is identified because of the existence of a Carbon Price.

The award of subsidies through TPAM lacks the simplicity of a decision rule that relates MAC to Carbon Price, but it reduces outlays on environmental costs and gains environmental integrity. This is because a permit/tax system forces firms to fund both abatement investment and Carbon Cost, duplicating firms' environmental costs and resulting in investment inertia.

Investment decisions based only on the relationship between MAC and Carbon Price will not direct abatement to the optimum social benefit. The challenge for the mechanism is to ensure that firms apply all of *EiQ* to abatement and don't engage in strategic behaviour to increase profits at the cost of abatement. With TPAM this challenge is addressed by a competitive tender process, in that firms will be incentivised to disclose valuable information through the potential award of subsidies.

2.2 *Calculating marginal abatement cost*

The Regulator must estimate the expenditure that would be required to reach an abatement target in the absence of private abatement. Once this is established, a threshold Marginal Cost of Abatement (MAC) can be calculated, i.e.

$$MAC = \frac{TKA}{TA}$$

Equation 4

Where

TKA: Full capital cost of purchase of technology to achieve abatement

TA: Total abatement of tCO_2e over period

Investment in abatement is an attempt to reduce a factor cost, i.e. the charge, in the form of a carbon price, by society for the use of its resource. Treating investment in abatement as a factor cost, changes its financial application. It can be understood as being funded from savings in production costs (i.e. not paying a carbon price), so such expenditure is focussed on saving factor costs rather than investing in future revenue earning potential. For this reason, the expenditure on technology to abate is a cost of abatement, not a cost of capital.

There is no inclusion of interest expense for the same reason that expenditure on abatement technology is a cost of production and not a cost of capital. Funds are applied as savings are made. For instance if a firm invests an amount that would have, instead, been a carbon price payment, the opportunity cost of abatement expenditure replaces the opportunity cost of the carbon price, so there is no net opportunity cost or interest rate increase from abatement investment.

Total abatement is calculated as follows:

$$TA = (Se - Sb)n$$

Equation 5

Where

TA: Emissions(annual) abated

Se: Emissions(annual) at end of period

Sb: Emissions(annual) at beginning of period

n: Length of period, in years

A much more complicated calculation would include increased annual emissions as a result of growth and decreased annual emissions as a result of abatement investment at unspecified points during the period. However, in the interests of simplicity and clarity of demonstration, a simpler calculation method is employed here. Whilst this may appear to be an unusual method for calculating abatement, as long as the same methodology is used by the Regulator and the firms, it is effective and unlikely to affect the efficiency of the allocation. If the Regulator wishes to maximize abatement during the period, it can issue permits to an annual emission level after abatement or at an optimum point during the period. As firms will still have to surrender permits equal to their annual emissions, this will ensure that firms are incentivised to abate as soon as possible to reduce the use of permits that will have value in the next period.

2.3 Competing to abate

After the Regulator calculates the Carbon Price, it is published so that firms can plan the abatement that they seek to achieve over a fixed period (let us assume 10 years) and tender their abatement bid to the Regulator. Once all tenders are submitted, the Regulator aggregates the abatement offered. As can be seen from Figure 2, the Regulator's MAC then becomes the threshold. Those firms that offer abatement below the Regulator's Marginal Cost of Abatement (MAC), will be eligible for permits to emit free of charge for the whole period, as a social contribution to their investment expenditure. Otherwise, firms will be required to pay the Carbon Price times their actual emissions to the Regulator annually for the 10 year period.

In Figure 2 illustrative MACs are provided. Assume that the Regulator's MAC is $100, the electricity generator has a MAC of $76, the cement manufacturer a MAC of $96 and the steel manufacturer a MAC of $250. In this case, the electricity generator and the cement manufacturer would pay no Carbon Price but would contract to deliver 33% and 26% abatement by the end of the period. The steel manufacturer would pay the Carbon Price.

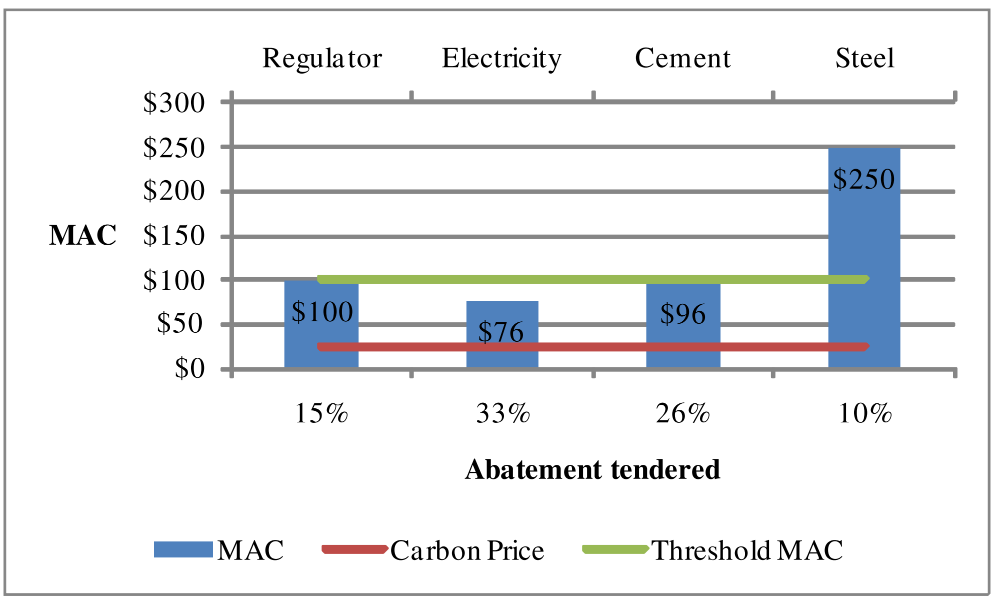

Figure 2: Permits allocated based on abatement offered

Where firms can supply cost-effective abatement, they are eligible for free permits that can be called ***Tier 1*** subsidies. In some cases, firms may be capable of offering even greater abatement than that which is achievable by investing their Carbon Cost. Under these circumstances, it is efficient to provide further subsidies to these firms to ensure that additional abatement is achieved through additional expenditure at a MAC lower than the Regulator's threshold, or other firms', MAC. For this reason, it is important to understand where more efficient abatement can be pursued within each firm. Therefore as part of the Tender process, all firms should provide at least 4 different abatement scenarios.

- The first scenario will detail the abatement possible by investing the Carbon Cost (projected emissions times Carbon Price) in abatement. (**Cheapest budget**)
- The second scenario will detail the abatement possible using an 'open cheque-book' approach to abatement, i.e., spend whatever is required to maximize abatement. (**Largest abatement**)
- The third scenario will detail the highest abatement possible at the lowest cost. (**Lowest MAC**)
- The fourth scenario will detail the abatement preferred by the firm which may involve an optimisation of maximized abatement with minimized cost and other factors pertinent to the firm. (**Optimised**)

The provision of this information will demonstrate MAC curves for each firm at different levels of technological investment. It establishes the basis for the award of *Tier 2* subsidies to firms to maximize country abatement at lowest-cost. Once the Regulator has collected and aggregated the reported MACs and the abatement information offered by the tenders, decisions can be made as to which firms should be required to pay the Carbon Cost to the Regulator for the period, which firms should be given free permits for the period, and which firms should be provided with additional subsidies for abatement because it is efficient to invest in abatement with those firms rather than pursue any other form of abatement.

2.4 Rolling out TPAM in Australia: examining the benefits of subsidies to the electricity sector

Emissions reduction faces a four-way trade-off between lowest MAC, lowest Carbon Price, highest abatement and highest investment. As highlighted by McKinsey & Co, the electricity sector has the highest need for investment to reach its abatement potential (McKinsey, 2009) but, equally, it faces strong competition for investment funds, high infrastructure debt, high emissions intensity and output pricing constraints. With the electricity sector's potential to substantially reduce national carbon emissions, it is logical for the Regulator to use abatement in electricity generation as its Control Cost in the absence of private abatement. A simple model using current data has been constructed to provide top-down cost estimates of meeting growth requirements, and replacing coal-fired generation with Concentrated Solar Tower Power (CSTP), Wind Power and combined cycle gas turbine (CCGT) generation[5].

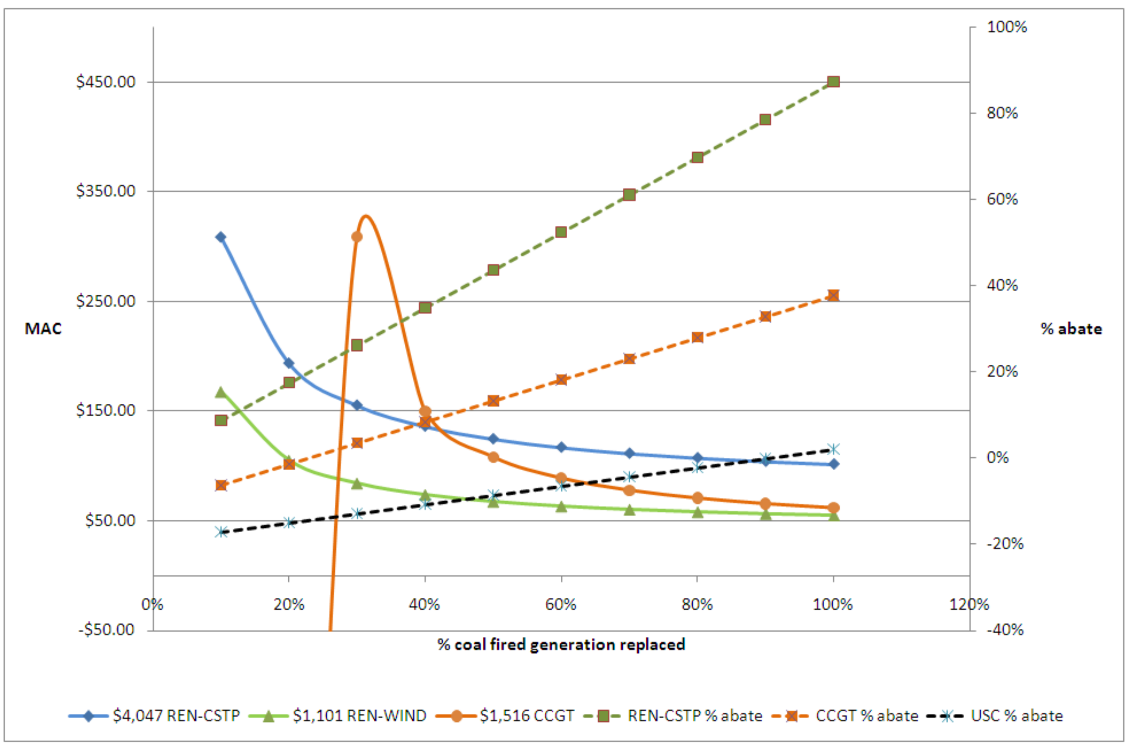

Figure 3: Generation Technology Comparison

What the model illuminates, is that whilst CCGT, CSTP and Wind Power all deliver abatement, their abatement potentials are vastly different. Figure 3 gives a comparison of

[5] The companion suite of CCGT, CSTP and Wind Power is chosen because both CCGT and CSTP can generate base-load power. CCGT is low-emitting, low capital cost, technologically stable, whilst CSTP is no-carbon, technologically proven and able to meet peak-load requirements. As Wind Power is cheaper than CSTP, it is included as an option to reduce the overall cost of providing renewable electricity. See appendix for more detail.

abatement potential and marginal abatement costs over the period of TPAM. What is of particular note is that because there is growth in generation (an estimated 12GW by 2021), no abatement is achieved over the period of TPAM by investing in only CCGT, until 23% of coal-fired plant is replaced. Because of the potential for additional emissions from growth-related generation, it is cheaper (lower MAC) to abate by investing in CSTP than CCGT until 44% of coal-fired plant is replaced. Another point to note is that 7.6GW of coal generation (26%) will be 40 years old, and 0.9GW of diesel generation will be 30 years old, by the end of 2021 which would indicate that it would be beneficial to replace at least those older facilities with new, low-carbon plant. Included for reference in Figure 3 is the abatement potential of Ultra Super Critical coal generation which can be seen as being unable to deliver abatement until 100% of the existing coal-fired stock is replaced, and then only 2% abatement is achieved.

To decrease the cost of abatement whilst maximising abatement potential, TPAM scenarios have been constructed as assorted combinations of CCGT/CSTP/Wind Power technologies rather than purely lowest-cost abatement. The possible Regulator Control Cost scenarios are summarised in Table 1. The Regulator could produce any number of such scenarios and choose the one that best suited its objectives. Here the **Optimised** option seeks to boost renewable electricity generation at a price that the economy could sustain. It does however cost more than it would cost to replace coal-fired generation with only CCGT. Investing only in CCGT caps abatement and does not allow the development of new industry, so the difference represents a subsidy to develop base-load renewable electricity and to boost abatement past the limits of CCGT. Equally, it would not be feasible to follow the **Lowest MAC** scenario because this scenario requires the replacement of all coal-fired generation with Wind Power which is not feasible as Wind Power does not provide base-load power. If we were to assume that the preference was to pursue the **Optimised** scenario then the Regulator would invest in a combination of CSTP and Wind Power, MAC threshold would be $93, the country abatement target would be 20%, the electricity sector could achieve 57% abatement over a 10 year period, at a cost that equates to \$24.10 per tCO_2e for large CO_2 emitters.

Table 1: Regulator control cost scenarios

Scenario analysis	Country abates	MAC	Abatement cost [6]	Carbon price	CSTP Inv	Wind Inv	Coal replace
Renewables for growth	0.3%	\$1,940	\$36,851	7.74	60%	40%	1%
Solar replaces 40 yr old plant	8%	\$164	\$83,765	17.60	100%	0%	27%
CCGT replaces all coal	14%	\$62	\$50,877	10.69	0%	0%	100%
Combination replaces 65%	15%	\$93	\$87,023	18.28	40%	22%	65%
OPTIMISED (66% renew)	20%	\$93	\$114,729	24.10	60%	40%	65%
Lowest MAC (Only wind)	31%	\$55	\$104,693	21.99	0%	100%	100%
LARGEST ABATEMENT	35%	\$84	\$180,512	37.92	60%	40%	100%

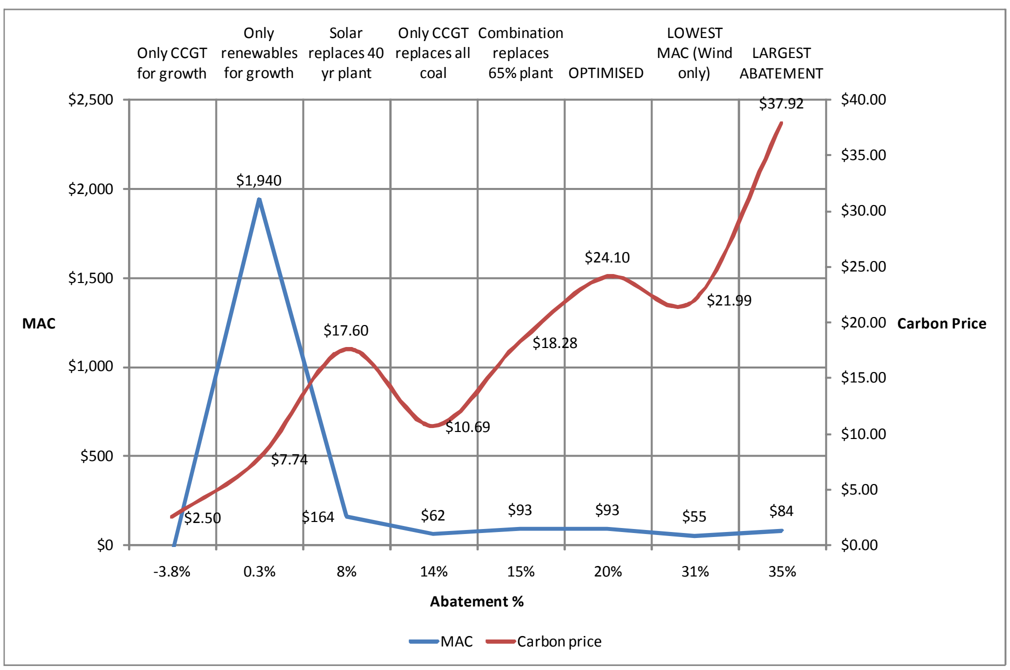

Figure 4: Regulator's Marginal Abatement Cost Curve

[6] Abatement cost is the investment cost less the present value of any private benefit from marginal cost changes in future periods as a result of reduced fuel costs. For a detailed explanation see Appendix.

Figure 4 gives a graphical representation of the Regulator MAC curve at different Carbon Prices. Note that MAC cost initially increases as renewable generation is implemented and then decreases as additional abatement is pursued through the replacement of coal-fired generation, followed by small increases resulting from more aggressive technology scenarios. As McHugh has highlighted, abatement cost calculations represent "*skipping across technologies to change levels of emissions reductions*" (McHugh, 1985, p59) rather than a predictably smooth upward curve with increasing abatement. He found that the Pigouvian level of tax and the net cost of control can be reduced by subsidizing firms to spend on ***technology stretching innovations*** rather than ***infra-marginal cost-reducing*** technology (McHugh, 1985). The benefit of increasing expenditure to pursue technology stretching innovations rather than affordable, but limited, abatement becomes apparent.

Having completed the Control Cost assessment, the Regulator would turn to the tender process. The electricity sector will, again, be used for illustration.

Table 2: Abatement without Tier 2 subsidies

	Regulator	**Electricity sector**
Annual Abatement	123MtCO_2e	82MtCO_2e
Abatement % Electricity Sector	57%	38%
Abatement % Country	20%	14%
Carbon price	$24.10	$25
Carbon cost	$115 billion	$54 billion
Marginal cost of abatement	$93	$65

As can be seen from Table 2, if $115 billion were spent in the electricity sector, 57% abatement could be achieved in the sector which equates to 20% abatement for the country. However, if $54 billion (the total Carbon Cost to the electricity sector) is spent in the electricity sector, the sector is likely to replace coal-fired generation with relatively cheap CCGT generation only. Whilst this gains abatement in the short-term, it hamstrings Australia with an ongoing 107MtCO2e of emissions per annum (20% of its total emissions) for the next 30 years. The only way that abatement can be increased is: if the Regulator itself builds renewable electricity generation with funds received from non-or-low abaters and goes into competition with existing electricity generators; or if the electricity generators indicate what their abatement potential is at increased levels of abatement expenditure, so that there is a possibility that *Tier 2* subsidies can be awarded to individual electricity generators where the additional funds will lead to increased levels of abatement and increased investment in renewable energy.

We turn now to a more detailed view of the workings of *Tier 2* subsidies when we consider a large Brown Coal Generator (1600MW generating capacity). The firm does not plan an increase in generation capacity over the 10 year period. The tender lodged with the Regulator could be:

Table 3: Brown Coal Generator Tender Details

Brown Coal Generator Tender	CHEAPEST BUDGET and LOWEST MAC (CCGT only)	LARGEST ABATEMENT (CSTP only)	OPTIMISED (Replace 50% with CSTP)
Abatement	72%	100%	50%
Annual emissions reduced ($MtCO_2e$)	14	19	9
MAC	$35	$50	$50
Cost of abatement	$4.7 billion	$9.5 bn	$4.7bn
Public funding reqd	$0	$4.8 bn	$0 bn

It can be seen from Table 3 above, that all scenarios deliver a MAC that is less than the Regulator's MAC. The challenge is to award subsidies for the scenarios that deliver abatement at the lowest cost to the Regulator. If the Generator spent its Carbon Cost, it could achieve 72% abatement from replacing all of its 8 generating units with CCGT or it could achieve 50% abatement from replacing 4 of its generating units with CSTP. Whichever technology is employed by the Brown Coal Generator, it is beneficial for the Regulator to award a *Tier 1* subsidy to the Brown Coal Generator.

As the Brown Coal Generator's **Largest Abatement** scenario provides for abatement at a cost-effective MAC, it is cost effective for the Regulator to consider *Tier 2* subsidies to the Brown Coal Generator. Eliminating all emissions from the Brown Coal Generator, would require $4.8 billion in additional funds. As the MAC of this scenario is less than the Regulator MAC, it would be a cost effective option. The award of *Tier 2* subsidies for abatement will however be dependent on the cost of abatement offered by the other tenders.

For comparison, let us consider the tender that might be lodged by a Black Coal-Gas Generator with a generation capacity of 3,500MW, of which 2,800MW was fired by black coal.

Table 4: Black Coal-Gas Generator Tender Details

Black Coal-Gas Generator Tender	CHEAPEST BUDGET	LOWEST MAC	LARGEST ABATEMENT	OPTIMISED
Abatement	14%	43%	100%	48%
Annual emissions reduced ($MtCO_2e$)	3	8	18	9
MAC	$179	$58	$97	$90
Cost of abatement	$4.5 billion	$4.5 bn	$17.6 bn	$7.8 bn
Public funding reqd	$0	$0	$13.1 bn	$3.3 bn

Here, the Black Coal-Gas Generator offers a **Cheapest Budget** tender to provide 2% additional capacity and replace an old 500MW coal-fired power station with CSTP providing 3MtCO2e of abatement at a cost of $4.5 bn and a MAC of $179. A MAC of $179 is higher than the Regulator's threshold MAC, so it is cost-effective for the Regulator to require the Black Coal-Gas Generator to pay its Carbon Cost to the Regulator and for the Regulator to award a *Tier 2* subsidy to the Brown Coal Generator to deliver the Brown Coal Generator's **Largest Abatement** scenario. It is however unlikely that the Regulator would trade-off generators against each other like this, as the source of *Tier 2* subsidies is more likely to come from the transport sector, although the threat of trade-offs like this is likely to induce truth-telling by generators. The Regulator is therefore more likely to consider supplying the Black Coal-Gas Generator with a *Tier 2* subsidy as either **Lowest MAC** or **Optimised** scenarios provide lower MAC's than the Regulator's MAC.

Using the Carbon Price to transition the electricity generators to low-carbon technology radiates benefits to the rest of the economy in the form of certainty of supply and price of electricity when facing carbon-constraints. So in the event that non-electricity sector firms miss out on subsidies in favour of investment in renewable electricity generation, non-electricity sector firms will still benefit from those subsidies in the form of improved, low-carbon electricity for the future. Providing *Tier 2* subsidies to a Brown Coal Generator to achieve 50% or even 100% abatement at the lowest MAC is efficient, and allows the Generator to: turn over high-carbon assets to low-carbon assets; reduce its Carbon Cost in subsequent abatement periods; and limit electricity cost increases due to the small factor costs associated with renewable energy.

A generator's high-carbon generating capacity will, as a shift to low carbon generation occurs, have a substantially reduced asset value, but with outstanding liabilities attached. By subsidizing the generator's transition to low-carbon electricity generation, the Regulator can enable it to keep generating electricity while changing its portfolio to a more socially desirable mix and still be able to service the costs of the, now undesirable, assets. Because abatement is pursued at lowest cost, the program is efficient and it encourages competitive behaviour among firms, but lobbying may make it difficult to subsidize the electricity sector to this extent. It should be remembered however, that providing subsidies to generators will limit the impact of a Carbon Price on the price of electricity. Irrespective of negotiations over the extent of *Tier 2* subsidies, TPAM offers a lowest-cost mechanism achieving greater efficiency than a CT or an ETS.

2.5 MACs derived from Levelized Energy Cost vs MACs derived in TPAM

McKinsey&Co have also calculated marginal abatement curves for Australia. Their finding was that Australia faces a Long-Run MAC of between $60 and $70 which is the additional cost of implementing the low-carbon option compared with the cost of the high-carbon option (McKinsey, 2008). This would appear to be substantially lower than the MAC calculated in our TPAM model. The primary difference is that McKinsey calculates MAC as the emission difference between *new* technologies rather than the cost of reducing emissions from *installed* technology over a short period of time.

Table 5: Generator LEC and MAC

Generator	Fuel price	LEC/MWh	tCO_2e/MWh	MAC
SCPf Super Critical Pulverized fuel (Coal)	$1.40/GJ	$44.79	0.8	
IGCC Integrated Gasification	$1.40/GJ	$66.60	0.82	No abatement
USC Ultra Super Critical (Coal)	$1.40/GJ	$45.26	0.74	$8
CCGT Combined Cycle Gas Turbine	$5/GJ	$58.08	0.43	$36
OCGT Open Cycle Gas Turbine	$5/GJ	$86.44	0.71	$463
WIND Wind Turbines	$0	$91.78	0	$59
CSTP Concentrated Solar Tower Power	$0	$116.48	0	$90

Source: (Wagner, 2010)

In the electricity industry, firms looking to invest in new technology will look to Levelized Energy Cost (LEC), the full equivalent costs of electricity generation over different life-spans, to assist with technology choice. LECs for the major generator types, and associated carbon intensity, are provided in Table 5.

Generation that has the lowest LEC is coal's SCPf which can be used as the benchmark for calculating the cost associated with reduced emissions from alternative technologies. The additional cost associated with reduced emissions provides a MAC for that technology. The MAC of CCGT at $36 is within the range of the McKinsey curve that has a coal to gas shift at below $50, and the MAC of Wind at $59 is also within the range of the McKinsey curve that has on-shore wind at just more than $50. (With a MAC of $90 it is surprising that CSTP was not even referenced in the McKinsey abatement curve). Figure 5 provides a graphical representation of the MACs of different electricity generation based on their LEC.

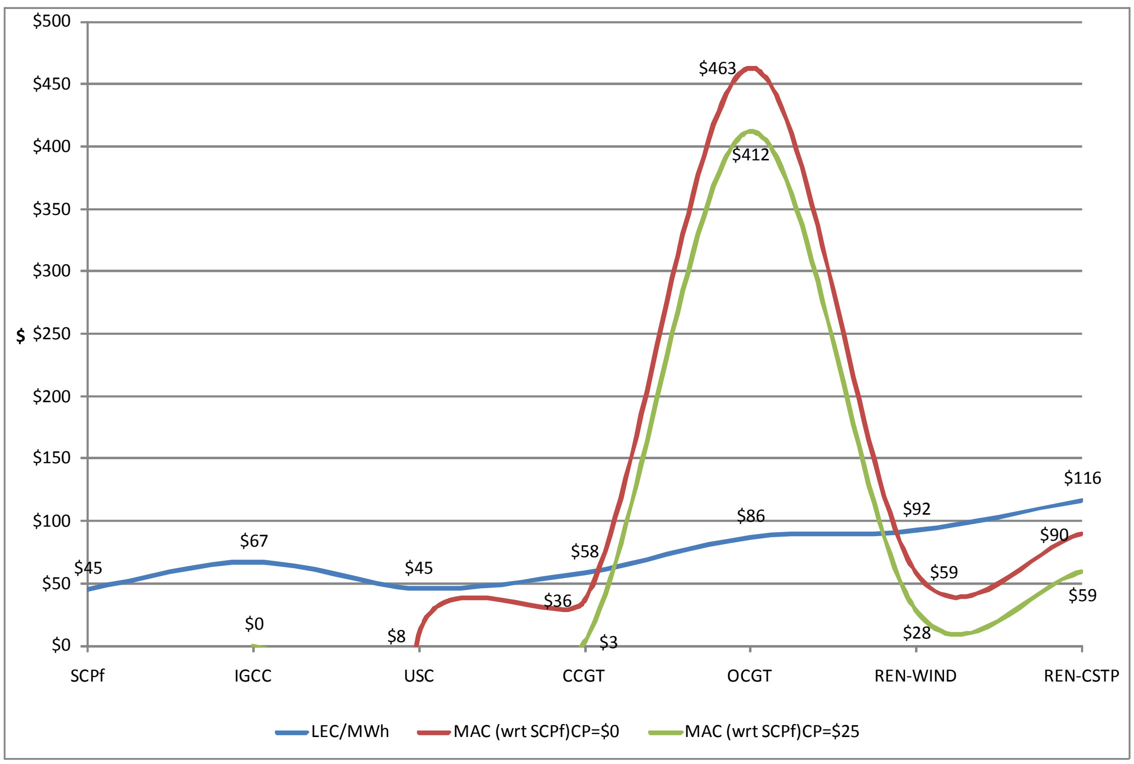

Figure 5: Abatement cost for electricity generation based on LEC

Turning to the calculation of MAC in TPAM, abatement is calculated as the cost of reducing emissions from installed plant rather than the increase in cost associated with reduced emissions from different technology types. Inherent in the difference between the calculations, is the reduced cost of financing since significant funding for abatement is provided from Carbon Cost not capital raising. Secondly, the cost of abatement is spread over only 10 years, the period of TPAM. Thirdly, TPAM incorporates the cost of growth in abatement cost, although it benefits from increased emission reductions from a high-carbon installed base. Fourth, although TPAM does not overtly include the cost of fuel in its calculation of MAC, the effect of fuel costs is included through the Present Value of Future Marginal Cost Changes to the cost of the technologies.

Table 6: MAC calculated in TPAM

Regulator		**MAC** (**TPAM**) **10 years**	**MAC** (**Replaced plant lifespan**) **12 years**	**MAC** (**New plant lifespan**) **30 years**
CCGT Only	Replace 65% coal, 2% growth *(Replace 100% coal)* *(Replace 30% coal)*	$83 *($62)* *($309)*	$69 *($52)* *($257)*	$28 *($21)* *($103)*
WIND Only	Replace 65% coal, 2% growth *(Replace 100% coal)* *(Replace 30% coal)*	$62 *($55)* *($84)*	$52 *($46)* *($70)*	$25 *($22)* *($34)*
CSTP Only	Replace 65% coal, 2% growth *(Replace 100% coal)* *(Replace 30% coal)*	$114 *($102)* *($155)*	$95 *($85)* *($129)*	$38 *($34)* *($52)*
OPTIMISED (60:40, cstp/wind)	Replace 65% coal, 2% growth *(Replace 100% coal)* *(Replace 30% coal)*	$93 *($83)* *($127)*	$78 *($69)* *($105)*	$31 *($28)* *($42)*

Where

MAC (TPAM) 10 years	The cost of abatement for the emissions abated over the period of TPAM (10 years). Note: this includes the capital cost of generation required for growth, but excludes the Present Value of Future Marginal Cost Changes.
MAC (Replaced plant lifespan) 16.5 years	The cost of abatement for the emissions abated over the remaining life of the plant being replaced. 12 years is used as an average of remaining lifespan of principal coal-fired power stations in Australia. Note: this includes the capital cost of generation required for growth, but excludes the Present Value of Marginal Cost Changes.
MAC (New plant lifespan) 30 years	The cost of abatement for the emissions abated over the entire life of the new plant. Note: this includes the capital cost of generation required for growth, but excludes the Present Value of Marginal Cost Changes.

Whilst the reduced financing costs, adjustment for future private benefits and high abatement from the installed base decrease MAC, the short period applied to the abatement cost and the inclusion of growth significantly increase MAC. The TPAM model also only includes combinations of CCGT, Wind and CSTP rather than the associated costs of SCPf, IGCC and USC which are not used, simply because they do not yield abatement when growth is included in the model. Costs per TPAM are included in Table 6 and show why MAC cost included in TPAM appears high as: it is spread over 10 years, applies to replacing 65% of the coal-fired generation base and includes growth in generation capacity. If MAC is calculated as the cost of abatement over the remaining life of the plant being replaced then it reduces by 16% to $78 (Combined CSTP/Wind). If MAC is calculated as the cost of abatement over the life of the new plant being installed, then it reduces by 67% to $31 from the TPAM benchmark. Also, MAC decreases across the board when a larger proportion of the coal-fired generation is replaced.

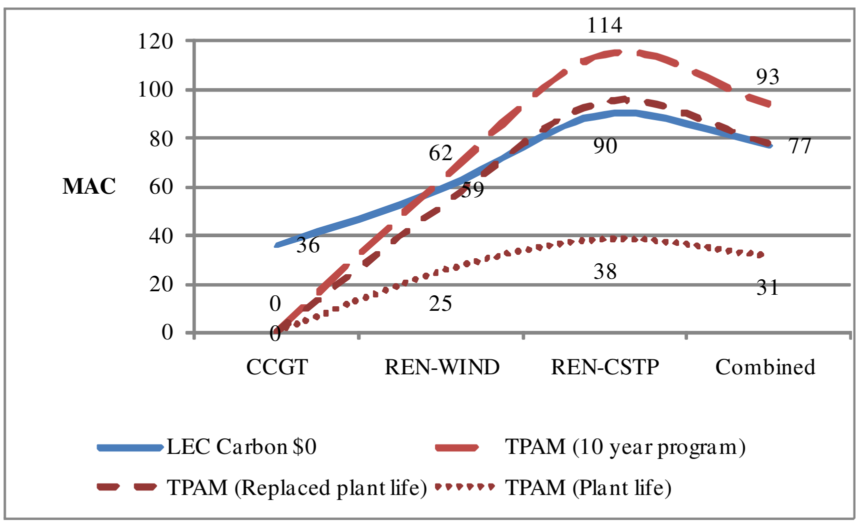

Figure 6: Comparing MAC calculated using LEC and TPAM

Figure 6 shows graphically how the TPAM calculated threshold MAC of $93 decreases to $31 when the abatement cost is spread over a longer time period. This indicates that applying subsidies to lowest cost abatement can make investment in low-carbon energy less costly than the $60 to $70 range indicated by McKinsey (McKinsey, 2008).

Adherence to the McKinsey MAC curves would involve following a sequential process of *infra-marginal cost reducing* abatement (McKinsey, 2008), which becomes more expensive than following a scenario-based approach where firms and the Regulator can combine abatement opportunities using different levels of *technology stretching innovation* to reach aggressive abatement targets. The ability to apply Carbon Price to a socially-optimal MAC is the integral benefit of TPAM.

2.6 Sensitivity analysis

The optimised scenario models a number of variables, movements in which will have an effect on the Carbon Price and the MAC threshold. Sensitivity to the cost of CSTP, the capacity of CSTP, and the size of the Present Value of Future Marginal Cost Changes are analysed.

2.6.1 *Sensitivity to the capital cost of Concentrated Solar Tower Power*

With the uncertainty surrounding the costs of CSTP, there is risk that the cost will deviate substantially from that used in the model. As can be seen from Table 7, a 20% decrease in the cost of CSTP reduces the Carbon Price and the MAC by 24%, whereas a 20% increase in the cost of CSTP increases the Carbon Price and the MAC by 24%.

Table 7: Sensitivity to CSTP cost

	\$5.4million (20% decrease)	**\$6.7million (base case)**	**\$8.1million (20% increase)**	**\$10.0million (50% increase)**
Optimum Control Cost (\$)	\$87 billion	\$ 115 billion	\$143 billion	\$185 billion
Optimum Carbon Price (\$/tCO2e)	\$18.24	\$24.10	\$29.97	\$38.77
Optimum MAC (\$)	\$70	\$93	\$116	\$150

If CSTP costs were 50% higher, the Carbon Price would increase to just under \$40/tCO2e (a 60% increase), which is higher than the preferred range for a price on carbon. In the event that CSTP costs were more than 20% higher, the **Optimised** scenario would only be feasible (ie a Carbon Price of under \$30) if 43% instead of 65% of coal-generation was replaced, or if 20%

of CCGT generation was substituted for CSTP generation to reduce the cost of abatement.

2.6.2 *Sensitivity to reduced CSTP capacity*

Concentrated Solar Thermal technology has been dogged by claims of low capacity, in the order of 24% without storage (IEA et al., 2010) and 34% with storage (EPRI, 2009), whilst the assumption in the model is that Solar Tower technology, with molten salt storage, can reach at least 60% capacity (Vogel and Kalb, 2010, NREL and Sargent and Lundy LLC Consulting Group, 2003).

Table 8: Sensitivity to CSTP capacity

SOLAR GENERATION REQUIRED	**34% capacity**	**40% capacity**	**60% capacity (base case)**	**70% capacity**
Optimum CSTP (MW)	36,712MW	31,206MW	20,803MW	17,831MW
Optimum Control Cost ($)	$179 billion	$157 billion	$ 115 billion	$103 billion
Optimum Carbon Price ($/tCO2e)	$37.63	$32.95	$24.10	$21.58
Optimum MAC ($)	$145	$127	$93	$83

Solar Tower technology, with molten salt storage, was demonstrated by the US Department of Energy in California between 1996 and 1999, a 17MW plant is currently in operation in Spain, with larger plant scheduled to start construction in Spain this year (2010). The impact of its capacity on the model is substantial, increasing the Carbon Price by 36% if capacity is maximized at 40%. For the Carbon Price to remain under $35 there would need to be a guarantee that capacity would reach 40%. In the event that CSTP capacity reached only 40% and the Carbon Price needed to be below $30, the OPTIMISED scenario would have to be adjusted such that 55% instead of 65% of coal-generation was replaced, or 10% of CCGT generation was substituted for CSTP generation to reduce the cost of abatement.

2.6.3 *Sensitivity to reduced Present Value of Future Marginal Cost Changes*

The Present Value of Future Marginal Cost Changes from the introduction of renewable energy generation is based on a calculation of a weighted average long range generation cost (or Reference LEC) for the National Electricity Market of $53.01 after the introduction of a Carbon Price of $25[7]. The Regulator, the National Electricity Market and the public may be more inclined to keep the price of electricity down by subsidising renewable energy investment cost over and above the abatement cost.

Table 9: Sensitivity to PV of MC changes

PV of FUTURE MARGINAL COST CHANGES	NEM REF LEC at CP=$25, full TPAM subsidy	NEM REF LEC (Pre-CP)	NEM REF LEC at CP=$25 (base case)	PV of MC changes decreased by 30%
NEM REF LEC ($/MWh)	$30.20	$26.41	$53.01	$46.92
CSTP PV ($/kW)	$ 0	$ 970	$2,666	$1,866
Wind PV ($/kW)	$ 0	$ 278	$1,033	$723
CCGT PV ($/kW)	$0	($1,545)	($243)	($170)
Optimum MAC ($)	$161	$139	$93	$114
Carbon Price ($/tCO2e)	$41.77	$35.91	$24.10	$29.41
Abatement cost ($)	$198,843	$170,953	$114,729 m	$139,970 m
CCGT introduced to reduce CP to $25 (%)	40% (reduce CSTP to 20%)	40% (reduce CSTP to 20%)	n/a	17% (reduce CSTP to 43%)

As can be seen in Table 9, attempting to keep REF LEC at the pre-Carbon Price level will increase the Carbon Price to $35.91 (which will have a corresponding increase in generation

[7] For details on the calculation of NEM weighted average REF LEC, see Appendix

costs), a 49% increase on the **Optimised** scenario. If the full cost of renewable technologies is funded by the Carbon Price, then the Carbon Price increases to $41.77, a 73% increase on the **Optimised** scenario. A Carbon Price of $41.77 may well be above a socially and economically acceptable level, in which case to keep the Carbon Price below $30, the replacement of coal-fired generation could be reduced from 65% to 37%, or 29% of CCGT generation could be substituted for CSTP generation with country abatement falling to 12% or 17% respectively.

To ensure a Carbon Price below $30/tCO2e, the **Optimised** scenario is robust to variations of up to 20% in the cost and capacity of CSTP and 30% in the Present Value of Future Marginal Cost Changes. Where the Carbon Price exceeds a social or economic ceiling, then either a reduced quantity of coal-fired generation can be replaced, or CCGT generation can be substituted for CSTP generation to reduce the cost of abatement.

Section 3 Why TPAM is more effective than a CT or an ETS

3.1 Optimal response in a world of uncertainty

Weitzman found that neither a price nor a quantity mechanism is an optimal response to induce firms to do what is best in an environment of uncertainty. *"Asking a firm to bear the extra risk involved in adopting a revenue schedule depending on uncertain variables not under its control may be infeasible or unacceptable"* (Weitzman, 1978, p685). (This is backed up by findings from Dixit and Pindyck that investment under uncertainty is subject to "hurdles", rates typically 3 to 4 times the cost of capital, required before investment is commenced (Dixit and Pindyck, 1994).) In fact, Weitzman found the optimal policy response to be where the Regulator provides each firm with "*a "price term" plus a weighted "quantity term", the weight depending in a well-defined way on specific features of the underlying* *situation*" (Weitzman, 1978, p683) with good policy instituting "*a reward structure which automatically encourages the cheap firm to produce more and the expensive firm less*" (Weitzman, 1978, p685).

In line with Weitzman's proposals, TPAM is left in place for an extended period to protect and encourage irreversible investment. What is different between Weitzman's proposals and TPAM is that Weitzman assumes that marginal benefit will always be determined at the Pigouvian optimum price and the quantity term must be sufficiently large to discourage variance from a desired quota. Conversely TPAM sets price subject to a number of constraints using price and the potential award of subsidies to direct firms to indicate their optimal quantity. The Weitzman model falls short of optimality because market uncertainties are unlikely to yield the optimum price[8] and it would be complicated to allocate a weighted quantity term. On the other hand, TPAM reduces uncertainty even further than the Weitzman model by increasing the flow of information between the Regulator and polluters.

The following sub-sections provide evidence of how TPAM, which directs economic activity under uncertainty, will be more effective than an ETS or a CT.

3.1.1 Regulator gains MAC certainty without the cost of revenue transfers

Like an ETS or CT, TPAM discloses firms' abatement costs. However, the process for disclosure involves a tender to abate, rather than just a revenue-raising license to pollute, or tax. Awarding subsidies based on the tenders that deliver the highest abatement, encourages competitive behaviour which will lead to truthful disclosure of firms' MACs. If firms fail to tender their full abatement potential so that they do not offer their lowest MACs or highest abatement to the Regulator, they may not win free permits to pollute, or *Tier 2* abatement subsidies, triggering multiple problems:

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[8]Eg, the EU ETS and the RECLAIM market

a) If their competitors tender their full abatement potential and gain the benefit of subsidies for expenditure in new technology, their competitors will gain first mover advantage (Lieberman and Montgomery, 1988) over them;
b) Their long-run marginal cost of production will be increased by the cost of carbon, ensuring an increased price to consumers with a reduced or no long-run low-carbon benefit giving the substitution benefit to their competitors;
c) Failing to minimize their production costs by winning free permit subsidies will cause shareholder dissatisfaction and possibly lead to share price deterioration[9].

It is therefore in the profit-maximizing interests of every firm to tender its most aggressive abatement achievable at the Carbon Price provided by the Regulator and at a variety of scenarios that disclose MACs. The inherent multiple-incentive (to gain a *Tier 1* subsidy to invest or pay for emissions, or gain a *Tier 2* subsidy) included in this tender process will provide a reliable mechanism (barring extreme strategic behaviour by firms) for the Regulator to understand each firm's MACs, and ensure expenditure on abatement to the most cost-effective abaters without the requirement for firms to transfer funds to government by acquiring rights (or paying a tax) to pollute. Eliminating the costs associated with transferring MAC information, makes TPAM more efficient than an ETS or a CT.

3.1.2 Cost of investment reduced

With an ETS or a CT each firm assesses its MAC and compares that to the Carbon Price. Where an electricity generator sees its MAC as $90 and compares that to a Carbon Price of $25, it will pursue no abatement. Where Carbon Price is too low to incentivise any abatement, each firm will still bear the Carbon Cost and will seek to pass that cost on to consumers, so society will bear the cost associated with a $25 Carbon Price but with no or little

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[9]There is evidence that share price is influenced by awareness of a company's environmental responsibility and innovation. ENGARDIO, P. & ARNDT, M. (2007) What Price Reputation? *BusinessWeek*, 70-79.

environmental benefit. If TPAM is in place, each firm will disclose its MACs to the Regulator and the firms with lowest MACs will be incentivised to abate. Allowing firms to transfer their Carbon Cost to abatement expenditure eliminates investment inertia associated with uncertain market activity. Firms will pay to abate or for someone else to abate on their behalf (where they pay the price, the Regulator will be abating on their behalf). Most importantly, TPAM provides substantial upfront funding to make assets more carbon efficient.

Whilst an ETS purports to equalize MACs over the long-run, it requires a computation of MAC based on future unknown technologies and costs which does not provide a reliable decision signal. Instability of MAC values, due to path dependence and technological breakthroughs (Morris et al., 2008), invalidates the theory that an ETS can allocate funds to abatement efficiently over the long-run. McKinsey, too, points to the risk of increasing the cost of abatement by spending on lowest capital intensity rather than lowest abatement cost due to rapid capital pay-back requirements(McKinsey, 2009).

Using MAC certainty gained through TPAM, the Regulator is able to direct abatement efficiently. Also, increased use of new technologies will lead to ‘learning-by-doing’ benefits that will reduce costs further (Jaffe et al., 2005). Subsidies that recognize the social benefit of abatement are more reliable for cost-effective resource allocation than a single, uncertain permit price based on the market perception of private costs and benefits.

3.1.3 Reduced risk reduces firms’ cost

Unlike an ETS, TPAM involves little cost uncertainty for firms. Understanding the extent of the Carbon Cost eliminates the need for pricing the risk of price variations into cost structures, thus reducing pass through to customers. Having to tender MACs to the Regulator would ensure that firms have a good understanding of their abatement costs. Firms look to gain certainty of costs through long-term contracts and TPAM does this. TPAM also allows inter-temporal smoothing of abatement. If firms believe that abatement costs will increase in the long-run, then those firms/industries that do not gain subsidies in the first fixed period, will seek to offer effective abatement in the second fixed period, because of the expected increase in Carbon Cost and/or the advancement of technology. So assistance will be provided to them when it is most cost-effective for them to spend on abatement. Fixing the Carbon Costs for a defined period is preferable to an ETS as it can provide firms, policy-makers and politicians with cost certainty to pursue contractually agreed environmental actions at lowest-cost.

3.2 Environmental outcomes improved by pursuing a 'Robin Hood' approach

Unlike an ETS or a CT, TPAM will only raise revenue if abatement can be offered more cost-effectively by, or through, a Regulator. A policy of taxing 'bads' to give to 'goods', a "Robin Hood" approach, uses revenues raised through the income effect to fund the substitution effect, thereby closely targeting the externality (Helm, 2005). So Carbon Cost is applied consistently across firms and all funds are spent on cost-effective abatement[10].

As noted by the Australian Academy of Science, technologies that would be optimal for addressing Australia's base-load power requirements, do not currently appear in Australia's energy mix because they are above the expected carbon price threshold(Australian Academy of Science, 2010). TPAM, however, would uncouple environmental outcomes from the relationship between MAC and Carbon Price, which is significant because climate change and environmental deterioration may not respond to action at the margins (Helm, 2005). Application of costs to abatement may be lumpy, (i.e., applied in 10 year spurts rather than on a hypothetically smooth MAC curve[11]) and in the future it may be found to have been more expensive to have acted before the mythical backstop technology appeared, but the backstop

[10] Only a percentage of the revenue raised by the Regulator may be subject to inefficiencies.
[11] Investment in abatement should by its very nature be lumpy and dependent on installed stock and available technology. Waiting for the perfect technology ignores the precautionary principle.

technology is reliant on investment, not equating MAC to Carbon Price.

As depicted in Figure 7, TPAM can direct abatement expenditure to all of the Brown Coal Generator's scenarios rather than abatement being reliant on the private benefit that results from a relationship between MAC and Carbon Price.

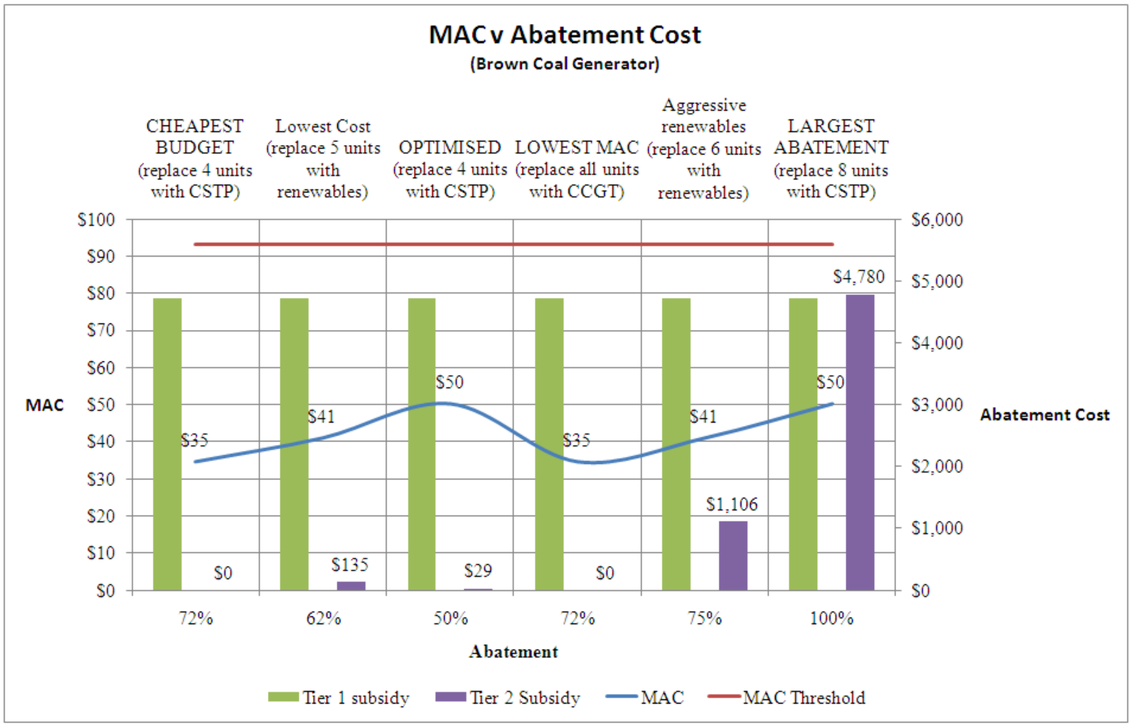

Figure 7: Generator Marginal Abatement Cost Curve

3.3 Comparing TPAM to other mechanisms

3.3.1 TPAM vs Free permit allocation

The evidence from both EU ETS and the US SO_x program is that free permit allocation does not drive significant investment in new technology. Whilst the US SO_x program encouraged *infra-marginal cost-reducing technology* switching between inputs and available technologies, it did not deliver *technology stretching innovations*(Carlson et al., 2000). Providing permits free to polluters, fosters a business-as-usual approach rather than a focus on substantial abatement (Neuhoff, 2008). A system that awards subsidies based on historical pollution protects current asset value without incenting socially optimal abatement. The subsidies provided by TPAM, however, will be focused on lowest-cost abatement rather than protecting high-emitting assets.

3.3.2 TPAM vs an energy tax

Because the major source of carbon emissions is from energy, the UK Climate Change Levy (CCL) was introduced in the UK to tax energy to foster abatement and encourage energy efficiency, with the revenue raised returned to firms as reduced National Insurance contributions. To reduce competitive pressures on emissions-intensive trade-exposed firms, Climate Change Agreements (CCA) were introduced as complementary measures to incentivise firms to reduce energy usage by offering substantial discounts in CCL liability. In addition, a combination of interest-free loans and enhanced capital allowances were made available to firms to increase their expenditure on abatement (House of Commons Environmental Audit Committee, 2008).

There are a few key differences between CCL and TPAM. Firstly CCL raises revenue which it then applies to reducing other taxes which doesn't incentivise action on abatement. As noted by the House of Commons Environmental Audit Committee 2008, applying a carbon price (in the form of the CCL and an Emissions Trading Scheme) was not effective in driving innovation because additional stimuli were needed (House of Commons Environmental Audit Committee, 2008). Secondly, applying the revenue raised to reducing other taxes benefited firms other than those engaging in abatement which reduced behaviour change. Finally, only limited funds were applied to interest-free loans and the enhanced capital allowances program to incentivise firms to invest in the "*step-changes in technology*" (House of Commons Environmental Audit Committee, 2008, p24) required to move to low-carbon production.

The similarity between CCL and TPAM is in the use of CCAs which would be similar in nature to the tenders submitted in TPAM with substantial reduction in liability for a successful contractual agreement. It is therefore interesting to note that the CCAs were regarded as successful in inducing behavioural change because of the focus on concrete action to stimulate change and the extra financial incentive of claiming a tax discount (House of Commons Environmental Audit Committee, 2008).

However, the effectiveness of the program was limited to efficiency measures rather than absolute emissions savings due to the lack of real incentives for firms to spend on abatement. Dr Ian Bailey from University of Plymouth stated:

> *"The greater issue is the affordability of that technology and the various either internal financing requirements or the need to go out on to open capital markets and persuade other investment organizations to invest in things which have got a very long pay back lead-time". (House of Commons Environmental Audit Committee, 2008, p25)*

He drew the conclusion that more public funding should be made available for firms to spend on abatement technology. Dr Bailey also suggested that "*what happens with the revenue from the Climate Change Levy could be as important as the price incentive itself*" (House of Commons Environmental Audit Committee, 2008, p35).

The findings on the UK's CCL, that firms require substantial incentives in the form of long-term agreements and public funding to embark on abatement, provides evidence that TPAM will be a superior mechanism for abatement. Applying the terminology of Andrew Warren, who provided evidence to the House of Commons Audit committee, TPAM will provide an integrated policy approach to abatement, combining 'carrots' (subsidies to abate), 'sticks' (payment of Carbon Cost if insufficient abatement offered) and 'tambourines' (competitive tender process to offer efficient abatement) to achieve desired environmental outcomes.

3.4 Evidence from the literature that combined tax-subsidy programs are efficient and effective

Having established that TPAM will be more effective than an ETS (both fully auctioned and free permit allocation), hybrid models and a revenue-neutral tax like the UK's CCL, it is important to establish what theoretical evidence exists to provide further support for a mechanism which encourages the use of charges combined with subsidies for socially-beneficial behaviour.

A study of US paper mills found that a 10% increase in emissions abatement capital delivered 6.9% lower emissions which translated into a 75% return on investment for society (Shadbegian and Gray, 2003)[12]. This is a significant finding in that it provides a substantial incentive for society to provide subsidies to firms that spend on efficient abatement.

However, it has been proposed that subsidies to firms for abatement actually lead to an increase in emissions, as additional profits attract new entrants into the market leading to greater industry emissions (Baumol and Oates, 1988, Kohn, 1992). The subsidy offered as free permits through TPAM is based on abatement and therefore does not attract new entrants on the basis of increased profits. A *Tier 2* subsidy that induces a new entrant will only be offered based on no or very low emissions, so it will not increase emissions. In addition, the introduction of a Carbon Price will ensure a uniform increase in marginal cost. Both firms engaging in abatement expenditure or choosing to pay the Carbon Price can increase their price because of the opportunity cost of the Carbon Price. The only differentiation between firms/industries will be the emission-intensity of their operations. Those that have the higher emission-intensity will have a larger increase in marginal costs and therefore price, triggering the desired income and substitution effects.

What about new entrants? They will face the same marginal Carbon Cost as their competitors which will provide a disincentive to new entrants that have a high-carbon production process.

[12] The large benefits are directly connected to the large estimated mortality impacts of particulates. Benefits will be different in the case of reducing GHG emissions, although reducing the potential for stochastic events which dramatically reduce quality and quantity of life may well provide benefits as large as the Shadbegian and Gray study.

Carbon Cost will only incentivise entrants that have a low-carbon production process, which leads to socially efficient production.

What about those firms exiting from the market as they are unable to achieve cost-effective abatement and unable to operate profitably when Carbon Costs have to be met? In line with socially efficient production, carbon intensive firms that cannot be profitable when carbon has a value need to exit the market. These exiting firms need to be offered the equivalent of free permits because, by definition, they are abating, although the quantum of subsidy would have to depend on agreed termination timeframes.

A system of a combined tax and subsidy was found to be efficient for controlling households' automobile emissions because "*any combination of the tax on emissions and the subsidy for emissions abated that sums to marginal pollution damage is economically efficient*" (Kohn, 1996 P459). Where we don't know the marginal pollution damage, if the tax-subsidy combination delivers the required pollution reduction at lowest cost, then efficiency is achieved. Also Conrad, in an analysis of power plants' investment in technology to abate SO_x emissions, found that a combined subsidy and tax system can solve market failure by directing the decision variables of the firm toward the socially optimum abatement investment (Conrad, 1991).

There is substantial evidence of the efficiency of tax-subsidy programs in water pollution control implementations. Because of uncertainty about the marginal social damage of pollution and politically induced budget constraints, pollution charges are often implemented below their optimal Pigouvian level. It was found in France that in addition to a pollution charge, a system of contracts with efficient polluters who offered information about abatement in return for compensation for abatement, ensured investment in abatement to the socially optimal level (Thomas, 1995). Similarly, Xepapadeas found that 'budget-balancing' contracts involving fines or subsidies was efficient, inducing individual polluters to follow optimal environmental activities (Xepapadeas, 1991). Empirical evidence on abatement expenditure by Chinese industrial firms also shows that a system of charges, most of which fund subsidies, has been effective in incentivising industrial water pollution abatement (Wang and Chen, 1999).

It can be assumed that uncertainty about the marginal social damage of pollution will encourage a sub-optimal setting of a carbon price under a CT, ETS or TPAM. However, TPAM accommodates a sub-optimal setting of Carbon Price because it funds efficient abatement when Carbon Price is well below MAC. This makes TPAM an efficient mechanism, as Fischer has found that welfare gains from support for innovation can be high when the carbon price has not been set at an optimal Pigouvian level (Fischer, 2008).

3.5 What are the possible shortcomings of TPAM?

3.5.1 Strategic behaviour by firms

Firms will seek to maximize subsidies and minimize expenditure through strategic behaviour. For this reason it is important to follow a competitive tender process to ensure that firms are not aware of thresholds. Firms must compete with each other to win subsidies rather than submit tenders that will guarantee the award of subsidies. A further reason for withholding threshold information is to avoid misleading firms. In the worked example above, the Regulator's threshold abatement level for the country is 20%. However, if a benchmark were applied to the electricity industry, the abatement benchmark would be 57%. The defining variable that establishes whether a firm reaches the threshold required is the MAC, not abatement percentage.

There are good reasons for also withholding the threshold MAC. Recall that TPAM requires a variety of information to be returned to the Regulator to establish where abatement funds should best be applied. Announcement of a MAC will encourage strategic behaviour by firms to tender abatement to the threshold rather than disclose their lowest MACs.

There have been a few studies that have suggested the use of subsidies to reduce strategic behaviour. (Kwerel, 1977) suggested returning subsidies for unused permits once limited permits had been allocated to emitters. Dasgupta, Hammond and Masking proposed a Vickery-Clarke-Groves (VCG) auction mechanism to get firms to disclose their permit demand schedules with a 2-part payment structure. Montero proposed a uniform price auction with part of the auction revenues returned to firms as incentives to bid truthfully(Montero, 2008). Despite the benefits of improving ‘truth-telling’ by firms, these mechanisms remain auction mechanisms which: transfer revenue to government; introduce additional abatement cost due to lack of price certainty; and duplicate firms’ costs because of the requirement to purchase permits for unabated emissions irrespective of the quantum invested in abatement.

Experimental economics has produced some interesting findings in the area of fixed price plus rationing mechanisms. TPAM is similar to non-price rationing of buyers, like initial public offerings, where the seller sets the price at which excess demand is expected in order to reward information revelation with preferential treatment. Papers that have explicitly analysed incentives in market games that involve rationing of buyers find that these mechanisms are often desirable to the seller and outperform mechanisms like uniform price auctions (Grimm et al., 2008). Grimm found that when demand is uncertain, bidders will overstate their demand to avoid being rationed (Grimm et al., 2008), which would suggest that firms will be highly incentivised to abate and disclose their true MACs to avoid missing out on subsidies.

3.5.2 Sub-Optimising the threshold MAC

There is risk that the Regulator may make a mistake in its Control Cost calculation. If the threshold MAC is calculated to be (incorrectly) very low, then all abatement will fall to the Regulator which will result in higher than lowest-cost abatement. If the threshold MAC is calculated to be (incorrectly) very high, it will allow abatement by firms where it could have been carried out at less cost by the Regulator. Calculating the Control Cost requires good information on abatement costs. To limit the potential for mistakes Regulators should consult widely and require technology providers to guarantee prices and performance[13].

The use of a 'benchmark' in TPAM does not introduce inefficient compliance costs for firms (other than establishing their MACs) because subsidies and abatement are not subject to the implementation of any one technology. In support of the concept of a benchmark, there have been suggestions that the introduction of best-available technology benchmarks would maximize the internal effectiveness and efficiency of the EU ETS (Grubb and Neuhoff, 2006). There was also no evidence that the US SO_x program was more successful than the implementation of a uniform performance standard (Carlson et al., 2000). These analyses would suggest that the use of a threshold MAC in TPAM would optimise abatement.

Furthermore, TPAM includes a safety net because the Regulator is able to access all firms' MACs. This allows the Regulator, where appropriate, to cut-off the award of subsidies once a desired abatement level is reached. By comparison, the market process has no safety net and as a result, markets, too, can make inefficient allocations as was evidenced in the EU ETS and the Reclaim NOx auction market. The existence of a benchmark, safety net and cost benefits make TPAM a desirable mechanism.

3.5.3 Risk of 'picking losers'

Awarding subsidies risks the tender process being labelled as 'Government picking winners' and substantial government involvement in the process of market-based incentives may be perceived as inefficient. However, the Regulator should be set up as an independent body, like

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[13] Aggressive SO_x emission reductions were achieved in Germany between 1983 and 1993 where electricity generators were given emission reduction targets based on guaranteed performance by technology providers. WATZOLD, F. (2004) SO_2 Emissions in Germany: Regulations to Fight Waldsterben. IN HARRINGTON, W. & MORGENSTERN, R. D. (Eds.) *Choosing environmental policy : comparing instruments and outcomes in the United States and Europe.* Washington, DC :, Resources for the Future.

the Reserve Bank, which, in effect, is managing a market mechanism that encompasses the demand for and supply of resources that are primarily of social, rather than private, value, at least in the short term. Whilst the establishment of an independent Regulator may appear to be considerable regulatory manipulation, it is no more than an ETS which involves regulatory manipulation to create and sustain permit markets by defining initial property rights, rules for allocation, enforcement, and then oversight to ensure competitive behaviour (Helm, 2005). Even though the Regulator would be awarding subsidies, the winners would be determined by competitive behaviour and environmental benefit, not the Regulator.

3.5.4 Failure to achieve abatement

Where firms do not deliver abatement offered in the tenders, it is a simple matter to calculate the value of the shortfall and to demand the ex post payment of Carbon Prices. This would be written into contracts. Whether penalties should also be involved and their magnitude, in extreme cases, is an open question.

3.5.5 International limitations

Whilst TPAM is compliant with reaching international treaty obligations in that it is based around a quantity target which is set by the Regulator, it does not fit easily into an international carbon market mechanism. This does not preclude international abatement activity. Where the Regulator decides on a very low Carbon Price, the most cost-effective way of meeting abatement objectives may well be to base the control cost of abatement on the purchase of international abatement opportunities, which the Regulator may take up where abatement opportunities within the country are not affordable.

It is suggested that the benefits of keeping funds within the country would tend to outweigh the benefits of diverting funds offshore, as national firms will gain competitive advantages over international competitors if abatement funds are invested locally. However, this is a debate beyond the scope of this paper. In terms of participating in international carbon markets, the proposal that TPAM is superior to an ETS predisposes the view that participation in an international carbon market will deliver inferior outcomes, and therefore is not particularly desirable.

3.5.6 Including forestry and land use change

There is no reason why foresters and land-owners should not tender their abatement proposals to the Regulator to gain subsidies which will serve as payment for their carbon sequestration. The problem lies in the reality that they are small firms without the resources to be individually involved in submissions to the Regulator. The Regulator, too, would not be interested in high volumes of low abatement tenders which would drive up transaction costs. However, it would be effective for land-owners to form syndicates which would be large enough to tender joint submissions and gain joint subsidies, thereby avoiding the inefficiencies of many small transactions. Forestry and land-use offsets have historically attracted relatively low offset value, so a fixed carbon price could have substantial benefits for these sectors.

Section 4 Conclusion

Following Weitzman (Weitzman, 1978), Okun (Okun, 1981) and Stiglitz (Stiglitz, 2002), it is clear that, in the face of the uncertainty, i.e. poor quality information that characterises the nature, extent and speed of global warming and the link with greenhouse gases, it is unwise to try to reduce carbon dioxide emissions using either a simple ‘cap and trade’ or carbon tax strategy. What is required is a hybrid price and quantity mechanism that reduces the uncertainty for both a regulator and firms. The Tender-Price Allocation Mechanism introduced here attempts to provide an appropriate scheme. The Regulator, acting as the caretaker of the environmental resource, provides information to the market in the form of a

Carbon Price. At this price, firms provide information back to the Regulator in the form of a tender to deliver abatement in return for subsidies. The information provided through the tender process ensures the efficient use of funds to deliver cost-effective abatement. For the ability to charge for pollution and reward for abatement, the Regulator becomes a 'visible hand' using information from firms to direct the optimum use of society's resources. Rather than standing aside to let a market dictate prices subject to an aggregation of private interests, the Regulator engages in the market process by bargaining with firms to supply cost-effective abatement using built-in incentives to solve investment and technological externalities without resorting to prizes, tax breaks, (Montgomery and Smith, 2005, Jaffe et al., 2005), Renewable Energy Targets/Certificates or Feed-in Tariffs.

We have argued that the Tender-Price Allocation Mechanism is superior to both emissions trading and carbon taxation. It reduces the costs of abatement for firms and increases cost-effective investment in abatement through the award of subsidies, not by Government but through the competitive actions of firms. Whereas Green found that permit price volatility directed investment away from renewable energy (Green, 2008), the findings here are that price stability and increased information allow increased abatement from the cheapest abaters. It also becomes possible to have investment in what is now high cost CSTP and Wind electricity generation rather than cheaper CCGT electricity generation. TPAM facilitates transition to a low-carbon economy but also garners investment for the technologies that will ultimately come to dominate in the long term.

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Appendix: Calculations, assumptions and sources of information

New Generation alternatives

Only 3 alternatives are considered for new generation to reduce the complexity of the model. Combined Cycle Gas Turbines (CCGT) is chosen as an alternative to coal as interim base-load generation for reduced emissions and ease of start-up/shutdown to compensate for possible renewable energy intermittency. Concentrated Solar Tower Power (CSTP) is chosen for already-available, renewable, zero-emission generation which allows for power generation to meet peak load requirements, with the ability to replace base-load fossil-fuel power generation (Arvizu, 2008, Australian Academy of Science, 2010). Wind power is chosen as a cheaper renewable energy option although its base-load power generation potential is limited. Geothermal and Carbon Capture and Storage are not included because they are technologies that are not yet proven or available for commercial roll-out. Technologies based on coal are not included because their abatement potential is insufficient to compensate for the increase in emissions from growth.

COSTS AND SOURCES OF CAPITAL COSTS USED IN TPAM ARE AS FOLLOWS:

CCGT: $1,273,000 (ACIL Tasman, 2009)

WIND POWER: $2,134,000/MW ((McLennan Magasanik Associates, 2008, Hearps and Wright, 2010) with 30% capacity (Hearps and Wright, 2010)

CSTP: $6,713,000/MW (Vogel and Kalb, 2010). US$ 5.7 million/MW for Tower technology with solar multiple of 4.4, and 16 hours of storage according to Kolb (SANDIA) analysis of Spain ‘advanced receiver’ installation (Vogel and Kalb, 2010).

With the potential to deliver energy during peak load times, Concentrated Solar Tower Power (with storage), can provide base-load power from renewable sources (SolarPaces, 2010). Studies point to the ability of CSTP to reach 73% capacity from Concentrated Solar Tower technology if sufficient heliostats are installed (NREL and Sargent and Lundy LLC Consulting Group, 2003).However, there is a widely-held view that CSTP is too expensive to implement, with the SolarTres installation in Spain at a cost of Euro 10 million/MW(Viebahn et al., 2008) often cited as evidence. It should be remembered that the SolarTres installation is the first commercial installation and as heliostats make up more than 50% of the cost of the plant(Kolb et al., 2007), it is expected that increased production and technology improvements will reduce the cost of heliostats alone from more than US\$250/m^2 (SolarPaces, 2010) to less than US\$100/m^2 if 9GW of CSTP is implemented globally (Kolb et al., 2007). With 10GW of concentrating solar power projects under development in the US (SEIA, 2010), it is likely that 9GW of CSTP will be installed over the next few years, thereby triggering the cost decrease in heliostats. This should provide justification for the suitability of using the NREL Sargent and Lundy (S&L) prediction of US\$3.6m/MW by 2020.

We are, however, reluctant to use the lowest cost option despite evidence that it is realistic. Therefore, we have chosen a much more conservative estimation of capital cost for CSTP, based on the “Kolb (SANDIA) advanced receiver Spain” scenario (Vogel and Kalb, 2010), using a solar multiple of 4.4 rather than 2.9, and a heliostat cost of \$138/m^2 (current cost is estimated to be \$164/m^2 (Kolb et al., 2007)) rather than \$96/m^2, included in the S&L analysis. We have also assumed the capacity of CSTP to be 60% instead of the S&L, Kolb, Vogel/Kalb predictions of more than 70%. The Kolb scenario predicts a total capital cost of US\$5,706/MW for large CSTP installations which we have converted at a rate of US\$0.85 to the Australian dollar.

ADJUSTMENT TO CAPITAL COST USED IN TPAM: CALCULATING THE PRESENT VALUE OF FUTURE MARGINAL COST CHANGES FROM ABATEMENT

Investing in renewable energy delivers a double benefit, namely abatement as well as decreased fuel costs. Abatement provides a social benefit, whilst decreased Short Run Marginal Cost (SRMC) delivers a private benefit. For illustration, consider the investment in CSTP for abatement. CSTP has a high capital cost and a low SRMC. However, with TPAM the funds for the investment in CSTP are applied from Carbon Cost, and should be excluded from the calculation of Levelized Energy Cost (LEC). Therefore applying all of the CSTP investment to abatement delivers substantial future period private benefits to generators.

The Present Value of Future Marginal Cost Changes (PVFMCC) is the capital sum required to increase the LEC of CSTP to a Reference LEC. The Reference LEC used here is a weighted average of Australia's National Electricity Market (NEM) after the introduction of a Carbon Price of $25. For details of this calculation, see the NEM Weighted Average Calculations below.

To ensure that a subsidy within a subsidy is not provided to energy abaters, the PVFMCC from CSTP, Wind Power and CCGT are calculated with reference to a weighted average LEC for the NEM after the implementation of a carbon price. This yields the following results:

Table 10: PV of Future Marginal Cost Changes

TECH	Investment cost ($/kW)	LEC ($/MWh)	LEC w/out capital cost ($/MWh)	REF LEC (avg NEM) ($/MWh)	PV of LEC diff ($/kW)
CSTP	$6,713	$116.48	$11.20	$53.01	$2,666
WIND	$2,134	$91.78	$16.60	$53.01	$1,033
CCGT (gas price = $5/GJ, Carbon Price = $25)	$1,273	$70.50	$55.74	$53.01	($243)

Therefore, to calculate the true cost of abatement, \$2,666/kW which represents the private benefit of switching to CSTP, needs to be subtracted from the investment cost of \$6,713, such that the abatement cost becomes \$4,047. The benefit of setting the Reference LEC at the average NEM LEC is that electricity price increases will be stabilised, especially if meaningful quantities of renewable energy are implemented. Equally, the abatement cost of Wind Power reduces from \$2,134/kW to \$1,101/kW but the abatement cost of CCGT increases by \$243/kW to \$1,516/kW to reflect the increases in generation costs that will result from implementation of CCGT technology.

NEM WEIGHTED AVERAGE CALCULATIONS OF: GWH GENERATED, REF LEC'S, CAPACITY FACTOR AND EMISSION INTENSITY

Data from ACIL Tasman's "Fuel Resource, new entry and generation costs in the NEM" (2009) is used extensively to calculate NEM averages.

- GWhs generated is calculated based on plants' registered capacity, with estimated capacity balanced to ESAA's Electricity Gas Australia 2009 Table 2.6 which gives generation by fuel by state. Capacity of each plant is estimated at the state average to deliver generation according to state fuel type.

- Cost of Generation for each plant is calculated using SRMC plus Fixed O&M costs for each plant multiplied by estimated generation.

- 'REF LEC' is calculated as the Cost of Generation divided by estimated generation; it excludes any financing costs of generation. This provides a reference cost of generation that can be used for comparison to renewable generation technologies.

- Weighted average emissions intensity is calculated using emissions intensity of each plant multiplied by GWhs generated, summed and averaged.

- Weighted average capacity is calculated using each plant's estimated capacity as a proportion of total capacity, summed and averaged.

Table 11: NEM Weighted Averages

	Est Gen (GWh pa)	Cost of generation CP0 ($M)	REF LEC CP0 ($/ MWh)	Cost of generation CP25 ($M)	REF LEC CP25 ($/ MWh)	Emission intensity (tCO2e/ MWh	Capacity factor (%)
CCGT	**3519**	**$202**	**57.58**	**$247**	**70.16**	**0.50**	**16%**
CCGT/Cogen	**91**	**$8**	**87.53**	**$9**	**101.90**	**0.58**	**6%**
Cogen	**167**	**$10**	**61.50**	**$13**	**76.51**	**0.60**	**12%**
Cogen/CCGT	**519**	**$26**	**49.21**	**$33**	**64.19**	**0.60**	**33%**
Engines	**6**	**$3**	**532.83**	**$3**	**558.17**	**1.01**	**1%**
OCGT	**7180**	**$725**	**101.00**	**$869**	**120.98**	**0.80**	**14%**
Steam turbine	**182045**	**$4,136**	**22.72**	**$9,084**	**49.90**	**1.09**	**70%**
Coal (Black)	**122016**	**$2,989**	**24.49**	**$6,002**	**49.19**	**0.99**	**68%**
NSW	71765	$1,828	25.47	$3,656	50.95	1.02	70%
QLD	50251	$1,161	23.11	$2,346	46.68	0.94	65%
Coal (Brown)	**55294**	**$814**	**14.71**	**$2,652**	**47.97**	**1.33**	**86%**
Natural gas	**4735**	**$334**	**70.49**	**$430**	**90.83**	**0.81**	**27%**
Grand Total	**193527**	**$5,111**	**26.41**	**$10,259**	**53.01**	**1.06**	**57%**
Source: ACIL Tasman 2009, ESAA 2009							

Calculating Emissions

CALCULATION OF EMISSIONS FROM CURRENT GENERATING BASE:

- Establish Capacity Utilization, ie the amount of GWh produced as a percentage of the total maximum capacity. For instance:
    - Total GWh capacity in 2007/08 was 424,466GWh which is a calculated figure from the total connected (excludes non-hydro renewable) generation available in 2007/08 of 48,455MW(ABARE, 2010) multiplied by total hours available (24*365) = 8760.
    - Total GWh produced from connected generation in 2007/08 was 228,600, of which coal generation was 80.8%, Natural gas was 13.2%, Hydro was 5.2%

and Other was 0.8%(ESAA, 2009) .

  - Capacity utilization is GWh produced divided by GWh capacity, which produced these results in 2007/08: coal/diesel 69%, gas 37% and hydro 17%.

- Establish Emission Intensity of fuel ie the amount of tCO_2e emitted in the process of generating electricity
  - tCO_2e emissions in the production of public electricity (Department of Climate Change, 2008).
    - Fossil Fuel Solid(Coal) = 181.3MtCO2e
    - Fossil Fuel Gaseous = 20.5 MtCO2e
    - Fossil Fuel Liquid(Oil) = 2.4MtCO2e
  - Per GWh of electricity produced
    - Coal = 184,709GWh
    - Gas = 30,175GWh
    - Oil = 1,829GWh
  - Emissions from generation: is tCO_2e divided by GWh produced, which produced these results in 2007/08: coal 0.98; gas 0.68; and diesel 1.0 tCO_2e/GWh.
- Emissions from installed generation is calculated as follows:
  - MW x Total hours available x capacity utilization x emissions intensity of generation
  - Coal: 8760 x 0.72 x 0.98 = 6181 tCO_2e/MW
  - Gas: 8760 x 0.34 x 0.68 = 2025 tCO_2e/MW

CALCULATION OF EMISSIONS FROM NEW GENERATION:

When replacing base-load coal-fired generators with CCGT or CSTP generators, the following need to be taken into account:

- Capacity utilization

- Capacity utilization for CCGT is calculated to be 85%, to provide base-load generation.
- Capacity utilization for CSTP is calculated to be 60%. (see Notes on New Generation alternatives)
- Capacity utilization for Wind is calculated to be 30%.
- Coal-fired generation historically has operated at 72% of capacity but when combined with Diesel, the capacity becomes 69%. When replacing Coal/Diesel with CCGT or CSTP which have 85% and 60% capacity respectively, a different quantum of generation needs to be built to allow for the change in capacity through the loss of coal generation. Therefore, if Coal is replaced by CSTP, then the MW required is calculated as follows:

$$Coal\ MW \times ((Capacity\ utilisation\ of\ coal))/(Capacity\ utilisation\ of\ CSTP)) =$$

- Emissions from generation:
  - CCGT: 0.43tCO_2e per MWh, equivalent to the average emission intensity for new entrant technologies for Queensland, NSW and Victoria (ACIL Tasman, 2009)
  - CSTP: 0
  - WIND: 0
- Emissions from new generation is calculated as follows:
  - CCGT: MW x 8760 x 0.85 x 0.43 = 3202 tCO_2e/MW
  - CSTP: MW x 0 = 0 tCO_2e/MW
  - WIND: MW x 0 = 0 tCO2e/MW

Projected Carbon Dioxide Emissions for Australia

Australian emissions of CO_2e as at 2008 were 576MtCO2e(Department of Climate Change, 2008). Following historic trends from 1990 to 2007, of:

- 2.1% increase per annum in emissions from energy
- 1% increase per annum in emissions from industrial
- 0.1% increase per annum in emissions from agriculture

These percentages are used to project emissions to 2011, the start year of TPAM. However, in the following areas historic emissions don't show a reliable trend, so the following assumptions have been used to project emissions for land use and waste.

- 0% increase per annum in emissions from land use change, as the historic emissions reflect substantial changes in land clearing regulation. There are not expected to be further substantial changes to land clearing regulation.
- 0% increase per annum in emissions from waste. Although the trend has been slightly downward over the last 17 years, it is assumed that immigration and population growth will halt that trend.

Using these assumptions as the basis for projecting future emissions, projects total emissions for Australia at the end of 2011 to be 607MtCO2e and emissions for the large polluters only to be 476MtCO2e (energy plus industrial emissions).

Electricity generation emissions of CO_2e as at 2008 were 204MtCO2e(Department of Climate Change, 2008).

- Electricity generation capacity as at 2007/08 is 51,068MW(ABARE, 2010)
- Include current energy projects due to be completed by 2011 of 3569MW(ABARE, 2010), such that generation capacity at the end of 2011 would be 54,637MW.

Using 2007/08 Generation Emission Intensity factors as calculated above yields carbon dioxide emissions for the year 2011 of 214MtCO2e from electricity generation of 54,637GW.