Submission to the Select Committee on Wind Turbines

Wind's effectiveness and CO_2 avoidance cost

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23 March 2015

This submission responds to the Terms of Reference items a, b, h and i:

a. the effect on household power prices, particularly households which receive no benefit from rooftop solar panels, and the merits of consumer subsidies for operators

b. how effective the Clean Energy Regulator is in performing its legislative responsibilities and whether there is a need to broaden those responsibilities

h. the energy and emission input and output equations from whole-of-life operation of wind turbines; and

i. any related matter.

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Executive Summary

The *Renewable Energy (Electricity) Act 2000* states:

"The objects of this Act are:

(a) to encourage the additional generation of electricity from renewable sources; and

(b) to reduce emissions of greenhouse gases in the electricity sector; and

(c) to ensure that renewable energy sources are ecologically sustainable."

Object (b) is, arguably, the principal objective because if it is not justifiable, on the basis of objective evidence, (a) and (c) are not justifiable either. This submission presents evidence that wind turbines are less effective at meeting objective (b) than is commonly assumed. Therefore, the CO2[2] abatement cost estimated from economic analyses is frequently understated.

This submission focuses on the **effectiveness** of wind turbines at reducing CO2 emissions from electricity generation in Australia and the impact of the **effectiveness** on the estimates of abatement cost ($/tonne CO2 avoided) by wind energy.

It is often assumed that effectiveness of wind energy is 100%, i.e., 1 MWh of wind energy displaces the emissions from 1 MWh of the conventional energy displaced. But it is usually much less, and values as low as 53% have been reported. To be clear, 53% effective means wind turbines avoided 53% of the emissions that, in the absence of wind, would have been produced by the generators that were displaced by wind generation.

Empirical analyses of the emissions avoided in electricity grids in the U.S. and Europe indicate that (1) wind turbines are significantly less effective at avoiding emissions than is commonly assumed and (2) effectiveness decreases as the proportion of electricity generated by wind turbines increases.

Unfortunately, neither the Clean Energy Regulator (CER) nor the Australian Energy Market Operator (AEMO) collect the CO2 emissions information needed for an accurate empirical estimate of effectiveness. Without good data for the emissions from power stations at time intervals of 30 minutes or less, estimates of emissions avoided by wind are biased high and have large uncertainty, i.e., we don't know what emissions reductions are actually being achieved by wind generation.

Under the Renewable Energy Target (RET), the proportion of wind generation is increasing so it is projected to supply about 15% of electricity by 2020 (interpreted from

[2] Throughout this document, CO2 means 'carbon dioxide equivalent'. 'Equivalent' means it includes CO2, CH4 and N2O with CH4 and N2O converted to their CO2 equivalent as defined by the UNFCCC.

the 2014 *RET Review Report*, Figures 11 and 13). In this case, effectiveness might approach as low as 53% by 2020.

When effectiveness is properly factored into calculations, wind energy has a high abatement cost; I provide a simple analysis using Levelised Cost of Electricity (LCOE) which estimates abatement cost of wind power at $168/t CO2 by 2020.

In comparison, the RET Review summarised estimates of the abatement cost of the Large Scale Renewable Energy Target (LRET)[3] at $32-$70/t CO2. These estimates, however, are likely underestimated as the analyses do not appear to take effectiveness into account, or at least not fully. If the economic analyses do not take effectiveness into account, and if effectiveness decreases to 53% by 2020, the estimates of abatement cost would nearly double to $60-$136/t CO2 with effectiveness included.

To put these abatement costs in context, the 'carbon' tax was $24.15/t CO2 when it was rejected by the voters at the 2013 Federal election. The current price of EU ETS carbon credits and the international carbon credit futures are:

- European Union Allowance (EUA) market price (10/3/2015) = €6.83/tCO2 (A$9.50)
- Certified Emissions Reduction (CER) futures to 2020 (9/3/2015) = €0.40/tCO2 (A$0.56)

Therefore, the LRET in 2020 could be 2 to 5 times the carbon tax, which was rejected by the voters in 2013; 6 to14 times the current price of the EUA; and more than 100 times the price of CER futures out to 2020.

Clearly, the RET is a very high cost way to avoid greenhouse gas (GHG) emissions. The rational policy decision is to close the RET to future investments. Or, as an interim measure, wind the target back to a real 20% of electricity generation.

I urge the Select Committee to consider: has the RET passed its use-by date? Why not allow Direct Action to do what it is designed to do, to achieve emissions reductions at the lowest cost?

Recommendations:

In consideration of the issues outlined in this submission, I recommend that:

1. The Government task an appropriately qualified agency, such as the Productivity Commission and/or Bureau of Resources and Energy Economics (BREE) with estimating the full economic cost of wind energy ($/MWh) as well as the CO2 abatement cost ($/t CO2 avoided).

[3] The current legislation requires the RET to generate 45,000 GWh in 2020, of which the LRET is to generate 41,000 GWh and the SRET 4,000 GWh. Therefore, the LRET will supply 91% of the RET. Wind power is projected to supply 83% of the LRET in 2020.

2. To get an early indication of the abatement cost of wind energy, contract an appropriately qualified consultant to:

    a. assemble the best estimates it can of the 'high quality' data required for a sophisticated analysis (this may include seeking information from generators with appropriate 'commercial in confidence' agreements), and

    b. estimate the CO_2 abatement cost with wind power (including all the hidden costs and the effects of higher electricity costs on the Australian economy).

3. Either, repeal the RET legislation which will:

    a. avoid what will become an escalating compliance cost of emissions monitoring if it remains in place, and

    b. allow Direct Action to operate without the RET being a major market distortion.

4. Or, if repeal of RET is not politically acceptable, close the RET to new entrants and incorporate the existing and committed RET installations into Direct Action.

5. Change the name of Direct Action to 'CO_2e Emissions Reduction Scheme' (CO_2e ERS). This should be technologically neutral with the primary selection criteria being objectively justifiable CO_2e avoidance cost (i.e. \$/t CO_2e avoided).

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1 Introduction

The *Renewable Energy (Electricity) Act 2000* states:

> "The objects of this Act are:
>
> (a) to encourage the additional generation of electricity from renewable sources; and
>
> (b) to reduce emissions of greenhouse gases in the electricity sector; and
>
> (c) to ensure that renewable energy sources are ecologically sustainable."

Object (b) is clearly the principal objective because if it is not justifiable, on the basis of objective evidence, (a) and (c) are not justifiable either. Consequently, the principal justification for favouring wind turbines (and other renewables) with legislation, regulation, direct subsidies and hidden cross-subsidies is to reduce CO2[4] emissions. But how much CO2 does wind generation avoid and at what cost?

There is a cost to such government interventions in the market. It is a cost to the Australian economy. Ultimately it is sheeted home to all Australians in the form of higher cost of living, fewer jobs, lower remuneration, less government income leading to poorer government services compared with what would have been if not for these government interventions. There are also the more visible cost increases like electricity prices. No one likes high electricity prices, not households who struggle with their household budget, not industry where energy costs can destroy their competitiveness, not politicians who wear the opprobrium. Clearly, emission reductions should be done at least cost and at no higher cost than is justifiable based on rational analysis of objective information.

As will be shown, wind turbines are a high cost measure with considerable uncertainty about the true costs and reductions actually achieved. This has implications for policy, particularly the utility of the Renewable Energy Target (*Renewable Energy (Electricity) Act 2000*). There are four main issues here: (1) the effectiveness of wind turbines in abating emissions, (2) the high cost of abatement, (3) the lack of data and (4) the usefulness of the Renewable Energy Target (RET). Each will be discussed in turn.

[4] Throughout this document, CO2 means 'carbon dioxide equivalent'. 'Equivalent' means it includes CO2, CH4 and N2O with CH4 and N2O converted to their CO2 equivalent as defined by the UNFCCC.

2 Issue 1 - Effectiveness

2.1 Definition & Relevance

The term "**effectiveness**" is used throughout this paper to refer to the ability of wind generation to reduce CO2 emissions relative to emissions in the absence of wind generation. 100% effective means the electricity generated by wind avoids all the CO2 that would have been emitted without the wind generation. Put another way, effectiveness is % reduction in CO2 emissions divided by % electricity supplied by wind.

Wind energy substitutes for energy from other generators, but not all the emissions of the other generators are avoided. There are several reasons for this. First, wind energy usually substitutes for the energy from the generators with the highest marginal cost; so wind tends to displace more gas than the proportion of gas in the grid mix at the time of substitution. Consequently, the average emissions intensity of the displaced energy is less than the average emissions intensity of the grid (Wheatley, 2013, gives an example on pp95-96). Second, some generators are kept on standby ready to take the load when the wind drops, still burning fuel and emitting CO2 but not generating electricity. Third, some generators shut down and then restart later. Starts and stops take considerable time (many hours for coal generators) and consume fuel. Fourth, when the wind blows, some generators are 'throttled back' to produce less power. However, they are less efficient when operating below their optimum output. Also, ramping power up and down consumes more fuel than operating constantly at optimum power, so they produce more emissions per MWh of electricity sent out.

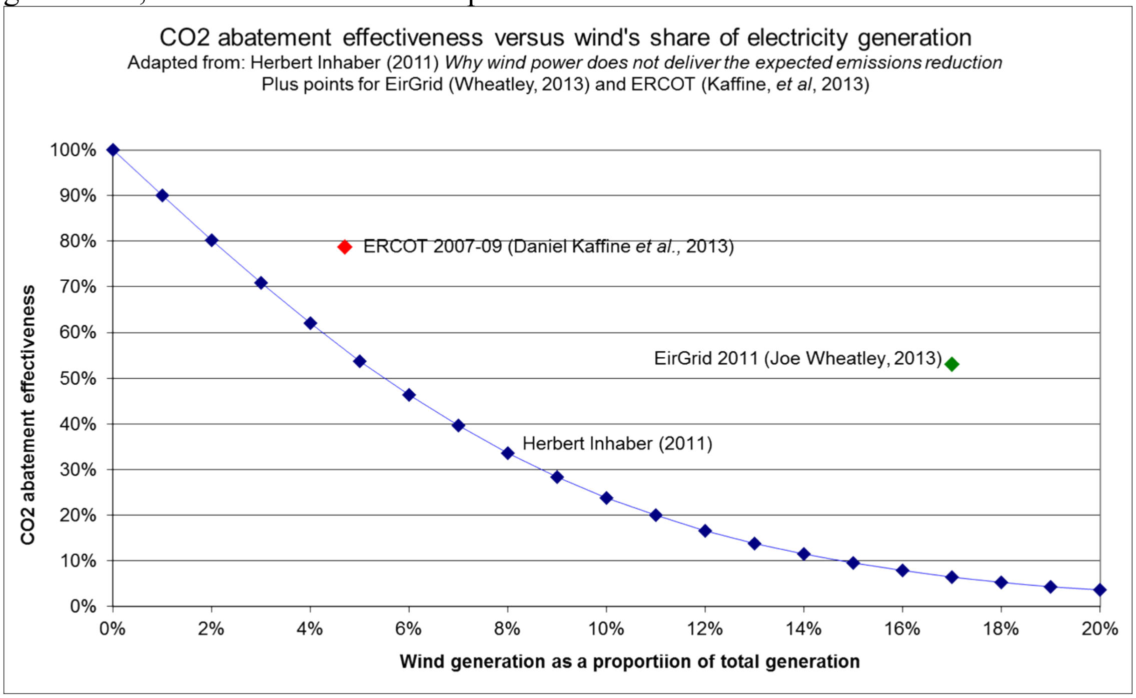
The **effectiveness** of wind turbines at abating CO2 emissions is an important input to correctly estimating the cost of emissions reduction. As **effectiveness** decreases the cost per tonne increases (all else equal). For example, if wind turbines are 50% **effective**, then the cost per tonne CO2 avoided is double that of estimates that do not take effectiveness into account. The key point here is that most estimates of the CO2 abatement cost of wind do not take **effectiveness** into account, but abatement costs increase as effectiveness decreases (see Issue 2) and means lower emissions reductions than planned.

2.2 Estimates of effectiveness of wind in other grids

Many studies have estimated the effectiveness of wind generation. Two recent, comprehensive studies using empirical data were of ERCOT (Texas) by Kaffine et al. (2013) and EirGrid (Ireland) by Wheatley (2013).

Figure 1 shows CO2 abatement effectiveness versus wind generation as a proportion of total generation for ERCOT (Texas) and EirGrid (Ireland) together with the Herbert Inhaber (2011) analysis of many published studies. All are from published analyses of empirical data. Critiques of the Inhaber paper revealed there were some misunderstandings and misinterpretations leading to the curve being too low, but the important point for this submission is the shape of the curve.

Figure 1: CO2 abatement effectiveness versus wind generation as a proportion of total generation, from three studies of empirical data.



The data in Figure 1 reveal two important issues. First, wind effectiveness is commonly less than 100%. Second, effectiveness declines as wind penetration increases.

A further issue, data quality, is discussed below.

2.3 Data quality

Wheatley did a preliminary estimate of emissions avoided using the electricity demand and emissions data published by EirGrid (this is similar to AEMO's data for electricity generated but EirGrid has better CO2 emissions intensity information). His preliminary analysis implied an effectiveness of 59%. A more sophisticated analysis using higher quality data (e.g. Wheatley, 2013, Tables 3 and 4) implied an effectiveness of 53%. (Appendix 1 is an excerpt from Wheatley, 2012, which provides a clear explanation of these concepts as well as an example). In this case, the high quality data reduces estimated effectiveness by 10% with a commensurate 11% increase in abatement cost. This highlights the need for high quality data. The SEAI, 2014, modelling study estimated effectiveness at 65% for all of Ireland and for a different year. The result is questioned here.

Many other countries collect the high quality data that allows effectiveness to be estimated, e.g. Ireland and other EU countries. Unfortunately, as will be shown in the next section, Australia does not.

2.4 Data availability

I have investigated the availability of high quality data for Australia but have been advised by AEMO that the data has not been collected. Details of my request and the AEMO response are in Box 1.

Box 1:

My request dated 21 January 2015, AEMO Information and Support Hub Call: 195322

> *"What I most want at the moment is (for **each individual generator unit, or station average**):*
>
> 1. *CO2-e emissions intensity (CO2-e/MWh) curves (for both as-generated and sent-out),*
> 2. *Thermal efficiency curves*
> 3. *Period when unit is consuming fuel but not generating*
> 4. *CO2-e emissions rate while consuming fuel but not generating, OR*
> 5. *No Load Fuel Consumption (% of Full Load Fuel Consumption)*
>
> *Since AEMO doesn't have this data, can you please tell me who does have it and how I can go about getting it?"*

AEMO Response 21 January 2015, AEMO Information and Support Hub Call : 195322

> *"Peter Lang,*
>
> *I am sorry but I don't have good news. We estimate the weekly GHG for power stations using the factors given in the spreadsheet here. The SCADA data can be found on our website www.nemweb.com.au then go to reports and archive then Dispatch_SCADA then select a day which opens a zip file with all the times of that day. The file has the SCADA data and DUID.*
>
> *This is what standard carbon contracts are settled off and equates to our CDEII data. Having said that, this will not add up to the total GHG as it only includes generators actually feeding into the market and it uses a general assumption on CO2-e/MWh.*
>
> *I am not aware of any way you can say for certain what the five minute emission is. The assumptions used by AMEO is aiming at getting the weekly emissions roughly right and we can only benchmark against the one year of CER data which has been released.*
>
> *I am not aware of thermal efficiency curves being made publicly available and AEMO doesn't have these. Having been preciously involved with NGERS data for a large energy corporation, I am not sure that anyone has that level of information."*

AEMO Response dated 22 January 2015, AEMO Information and Support Hub Call: 195322:

> *"Regarding your earlier comments about AEMO needing to make the data available. We can bring it up with industry and COAG to see if they believe that there is sufficient market benefit to warrant a rules change. The issue AEMO has at the moment is that the information is not shared with us and in some cases may not already exist. We welcome feedback and suggestions for improvements however we will not be able to collect this data in the short term. "*

However, the lack of AEMO data need not preclude the development of estimates for effectiveness in Australia. I expect a company such as ACIL-Allen, which has done considerable research on emissions from the power sector including providing the emissions intensity and related data for AEMO, may be able to develop reasonable estimates of the needed data.

2.5 Data needed

Previous studies have established the quality of data needed to estimate effectiveness. Such data should include measured emissions data, ideally at 5 minute intervals but not greater than 30 minute intervals. If measured emission data are not available, emissions can be estimated from the following variables for each individual generator unit (ref. Wheatley, 2013, Tables 3 and 4). Required data include the following or equivalent:

- Emissions when consuming fuel but not generating electricity.
- Emissions factor (kg CO2/GJ) for the fuel consumed
- Thermal efficiency (or heat rate) *curves* for each individual generator unit (or points and slopes as per Wheatley, 2013, Table 4)

The mean and 95% confidence intervals for each of the above are also needed.

US EPA requires emission be measured in the exhaust stack at 15 minute intervals. The EU requires emissions are estimated using the data listed above.

These data are not collected by CER or AEMO. In fact, AEMO doubts that anyone has the needed data (see Box 1).

3 Issue 2 - Uncertainty and biases

3.1 Uncertainties

When a statistical analysis is conducted the results are given as, for example, 45% +/- 3 percentage points at 95% confidence level (or 19 times out of 20). Estimates of the effectiveness of wind turbines and of the cost per tonne avoided vary greatly. Clearly these estimates have high uncertainty (large margin of error). It is important to quantify the uncertainty for these analyses.

Uncertainty is defined by the confidence interval. For example, we might estimate the effectiveness as 50% +/- 20 percentage points at 95% confidence. Similarly, we might estimate the CO2 abatement cost at $100/t +/- $20/t at 95% confidence.

NGER, Chapter 8 Assessment of Uncertainty defines the requirements for reporting uncertainty in emissions estimates and the methods to be used for estimating uncertainty. However, the information available is not applicable at the short time intervals required for estimating the emissions avoided by wind generation.

3.2 Causes of uncertainty

Three main causes of uncertainty relevant to estimating effectiveness and CO_2 avoidance cost are:

1. Statistical uncertainty
2. Lack of data
3. Lack of calibration, lack of checks from alternative estimating or measurement method. Lack of validation.

3.3 Biases

Estimates of the CO_2 emissions caused by power plant ramping and cycling may be biased for a number of reasons:

1. Thermal efficiency of power plants reported by CER and used by AEMO are linear through the range of power output from minimum to maximum power. In reality, this is a curved function (see examples in Appendix 2). Using the linear approximation understates the emissions when generators are running at less than optimum power so they underestimate CO_2 emissions when wind power is high and overestimate it when it is low. This makes wind energy seem more effective than it actually is at reducing emissions.

2. Fuel is consumed when no electricity is being generated, e.g. during warm and hot stand-by, spinning reserve, start-up and shut-down. The emissions are claimed to be included in the total annual emissions reported by CER and in the average emissions intensity (t CO_2/MWh), so the total emissions reported per year should be correct. However, the emissions are not being attributed to the correct time they were emitted. This means when the wind is generating at high power, emissions are understated and when wind is generating at low power, emissions are overstated (e.g. because the spinning reserve emissions are not included). This again makes wind energy seem more effective at reducing emissions than it actually is.

3. Whereas the Emissions Intensity published by AEMO (code CO2EII) should be multiplied by power sent-out from the power station, AEMO does not publish the power sent-out from the power station at sufficiently close time intervals for this data to be used for estimating the emissions caused by ramping and cycling (or the emissions avoided by intermittent generators). Therefore, we have to estimate the emissions sent out by subtracting power used by 'Auxiliaries' from power 'as-generated' (code SCADAVALUE). The SCADAVALUE is a measurement of power at a point in time and therefore, not as accurate as the metered energy sent-out. Bias occurs because the power used by Auxiliaries is not a linear relationship to the power generated. It is partly constant and partly variable in proportion to generation. Therefore, emissions are understated when the generator is operating

at low power (i.e. when wind generation is high) and overstated when the generator is operating at high power (i.e. when wind generation is low). This again makes wind energy seem more effective at reducing emissions than it actually is.

4. The emissions intensity values published by AEMO (code CO2EII) are calculated on the basis of generation sent-out as measured at the 'Regional Reference Node' for each state. Emissions are calculated by multiplying generation sent-out by emissions intensity sent-out (code CO2EII). However, this causes another source of bias. Because the transmission lines from wind farms are longer and lower capacity on average than from the fossil fuel power stations, the losses in transmission are likely to be greater for wind turbines than for fossil fuel power stations (on average). Furthermore, the losses from wind are greater when wind is generating high power than when generating low power. Yet again, this makes wind energy seem more effective at reducing emissions than it actually is.

3.4 Implications

The implications are:

(1) Abatement from wind is very uncertain and the estimates of emissions avoided are overstated.

(2) Current policy is flawed because the justification is based on analyses of inadequate data and has not properly accounted for the effectiveness being less than 100%,

(3) A study by an authoritative government agency should be commissioned to do an economic analysis of the full economic cost of the RET, the emissions avoided and the cost per tonne CO2 avoided. For fast results a study by a consultancy could be done initially.

(4) CER is not gathering the data needed to estimate the emissions avoided by intermittent generators like wind and solar. However, I am not recommending the regulations be modified to collect the data (see Recommendations).

4 Issue 3 - Abatement cost ($/t CO2 avoided)

4.1 Background

As stated previously, abatement cost is dependent on effectiveness, e.g., if the effectiveness is 50%, then the CO2 abatement cost is twice that calculated when assuming 100% effectiveness. Many analyses assume 100% effectiveness, so they understate the true CO2 abatement cost of wind turbines. In this section I provide an estimate of abatement cost for three values of effectiveness.

There is a variety of methods used to calculate the CO_2 abatement cost of a technology. Here I use a simple approach using nominal values for Levelised Cost of Electricity (LCOE) based on BREE Australian Energy Technology Assessment (AETA) 2012 and 2013 Update.

4.2 Additional costs

The LCOE quoted by AETA is for the technology only. In reality, integration of wind turbines imposes many other costs onto the network and other generators. For estimating the cost per tonne CO_2 avoided by wind, the LCOE needs to include:

1. The increased grid costs of including intermittent energy sources in the grid. These costs become increasingly significant as the proportion of electricity generated by wind increases.

2. Costs transferred to the dispatchable generators. Mandating renewable energy to substitute for existing dispatchable power plants transfers an array of costs onto those plants. For example, the existing dispatchable plants' fixed costs must be paid for by selling less electricity, so they must increase their price for the electricity they send out. A second example is the extra cycling of coal plants which incurs high costs.

3. The fact that more Open Cycle Gas Turbines (OCGT) and fewer Combined Cycle Gas Turbines (CCGT) are built than would be the case if not for the need to have highly flexible backup for wind power. OCGT are more flexible and responsive than CCGT but produce around 50% more emissions and are higher cost. This leads to higher electricity costs and higher CO_2 emissions.

4. Decommissioning of wind turbines at the end of their economic life and of other generators that are permanently displaced.

Mandating wind power (as the RET does) is increasing the cost of electricity not only by its own energy being twice the cost of the generators it replaces, but also by the items noted in the four points above.

A simple way to estimate CO_2 abatement cost (\$/t CO_2 avoided) is explained by Oliver and Jackson (2000):

> The 'specific incremental cost' (SIC) of the abatement technology per unit of environmental abatement is calculated by deducting the cost of electricity supplied by the baseline technology (C_B) from the cost of electricity supplied by the abatement technology (C_A), and dividing this by the amount of abatement (tonnes of avoided emissions) that the new technology will provide (Eq. (2)):

$$SIC = (C_A - C_B)/(E_B - E_A), \qquad (2)$$

where E_A is the emissions per unit of electricity supplied from the abatement technology and E_B the emissions per unit of electricity supplied through the baseline.

The costs should include the additional costs listed above.

4.3 CO2 abatement cost vs effectiveness - an illustrative calculation:

I have calculated abatement costs as a function of effectiveness for different fuels using the method explained in Section 4.1 with inputs based on BREE AETA 2012 report and 2013 model update. Appendix 3 details the method, calculations and the intermediate results, with assumed inputs listed in Table 1. The effectiveness figures used represent:

100% = the common assumption, i.e. wind power is 100% effective at avoiding the emissions from the generators it displaces;

80% = the effectiveness of ERCOT for 2007-2009, when wind power generated 4.7% of total electricity generation – c.f. Australia 2.9% in 2012-13;

53% = the effectiveness of EirGrid in 2011, when wind power proportion was 17% of total generation (similar to what Australia's proportion of wind power is likely to be in 2020 if the RET legislation remains unchanged).

Table 1: Assumed LCOE of *existing* coal and gas generators and NEM average; and LCOE of *new* wind plants as well as CO2 Emissions Intensity (EI) inputs used to calculate the CO2 abatement costs shown in Figure 2.

Technology	LCOE $/MWh	CO2 EI t CO2/MWh
Coal	$30	1.0
Gas	$80	0.5
NEM avg.	$50	0.9
Wind	$110	0.0

For comparison with these assumed values of LCOE and EI, Table 2 lists estimates from Bureau of Resources and Energy Economics (BREE) Australian Energy Technology Assessment (AETA) reports, 2012 and 2013 Update. BREE provide these average LCOE and emissions intensities for use in Australian economic modelling.

Table 2: LCOE and CO2 emissions intensity for coal, gas and wind technologies; source [AETA 2012 Report and AETA 2013 Model]

Parameter:	LCOE	LCOE	CO2 EI	
Source:	**AETA 2012**	**AETA 2013**	**AETA 2012**	**AETA 2012 Table No.:**
Technology:	**$/MWh**	**$/MWh**	**t CO2/MWh**	
Brown coal	26	not stated		3.1.2
Black coal	30	not stated		3.1.3
CCGT	103	89	0.368	3.2.1 & 4.16
OCGT	215	195	0.515	3.2.1 & 4.19
Wind	116	111	0	4.29

The results shown in Figure 2 are derived from the values in Table 1 (see analysis in Appendix 3). Figure 3 assumes the hidden costs of wind energy outlined in Section 4.2, points 1 and 2, are $20/MWh higher than for the dispatchable technologies, giving an LCOE for wind of $130/MWh. The $20/MWh figure is based on Nicholson and Brook (2013) '[Counting the hidden cost of energy]'. This article summarizes an [OECD/NEA study] which gives 'mid' estimates for the hidden cost of wind were $17/MWh for USA and $22/MWh (interpolated for 15% wind energy penetration) across six OECD countries, compared with $0.5-$0.9/MWh for the dispatchable technologies, gas and coal.

Figure 2: Estimated CO2 abatement cost at 100%, 80% and 53% effectiveness with wind substituting for coal, gas or the average NEM emissions intensity and cost of electricity; assumed LCOE of wind is $110/MWh (refer Table 1 for the assumed LCOE and emissions intensity used for each generator type).

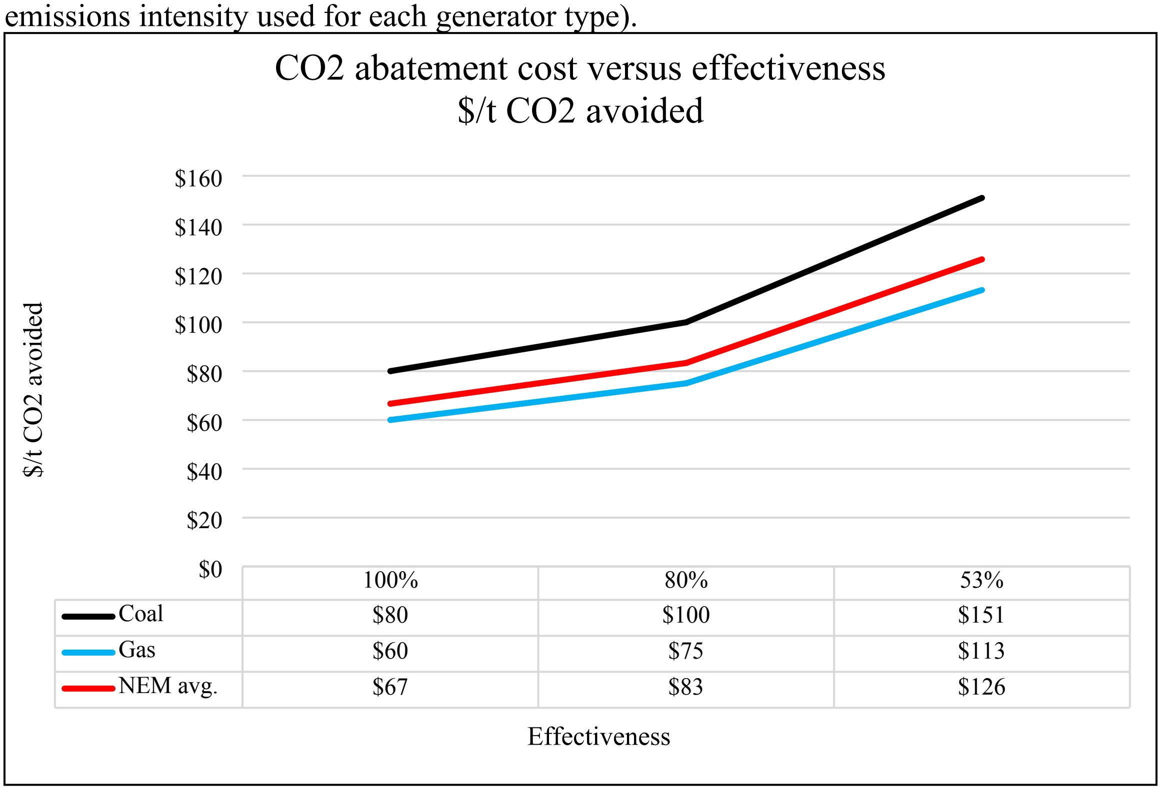
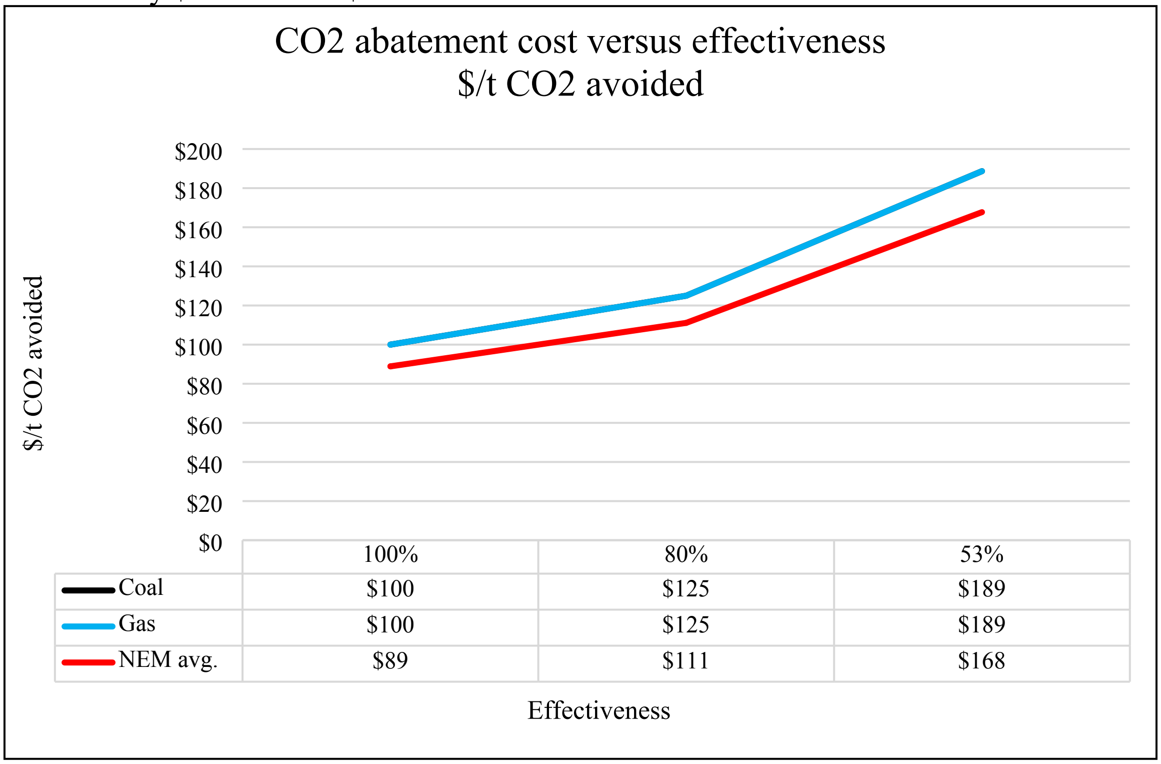


Figure 3: Estimated CO2 abatement cost; inputs as for Figure 1 except wind LCOE is increased by $20/MWh to $130/MWh to include the hidden costs mentioned in the text.



	100%	80%	53%
Coal	$100	$125	$189
Gas	$100	$125	$189
NEM avg.	$89	$111	$168

Examination of Figures 2 and 3 shows that CO2 abatement cost increases as the CO2 abatement effectiveness decreases, i.e., abatement cost is inversely proportional to effectiveness. This highlights the importance of effectiveness in correctly estimating the CO2 abatement cost.

It is worth considering that if the RET remains as currently legislated then the wind proportion of electricity generation in Australia may reach around 15% of total generation by 2020. Based on the 53% effectiveness of the EirGrid at 17% wind proportion, we could assume for this example, the effectiveness of wind turbines in Australia in 2020 might be similar to EirGrid in 2011. For the assumptions of $130/MWh LCOE for wind with hidden costs included, the other inputs in Table 1 and wind displaces the average NEM emissions intensity, Figure 3 shows the CO2 abatement cost would be about $89/t CO2[5] if 100% effective or $168/t CO2 if 53% effective. For comparison, economic analyses submitted to the RET Review (Section 5.6) estimated the abatement cost with the LRET (which is mainly wind) at $32-$72/t CO2.

I have examined the ACIL-Allen report, and the analyses by Deloitte, Frontier Economics and The Centre for International Economics. They don't explicitly address effectiveness. Therefore it is reasonable to assume that effectiveness is not fully

[5] Comparison with other estimates suggests the abatement cost figures estimated by this simple LCOE analysis are reasonable. Other estimates are included in Appendix 3. However, note that they are based on different assumptions, are for different years and periods and do not take effectiveness into account.

accounted for in their analyses and consequently their estimates of $32-$72/t CO2 are likely underestimated.

It should be noted that the $168/tonne abatement cost (Figure 3) is about seven times the rate of carbon tax that was rejected by the electorate at the 2013 Federal election.

5 Issue 4 – Renewable Energy Target (RET)

Under the Renewable Energy Target (RET), the cost of abatement is high while reductions are uncertain. While this Select Committee is dealing with wind turbines, the same arguments apply to solar which is even higher cost.

The RET mandates 41,000 GWh of large scale renewable energy by 2020 regardless of cost. I interpret from the RET Review Report, Figures 11 and 13, 41,000 GWh would be about 18% of generation in 2020. Wind would provide most of this, so it may supply around 15% of generation by then. Based on the estimates in the previous sections, the effectiveness may approach 53% by 2020, in which case the CO2 abatement cost may approach $168/t CO2 (Figure 3).

Direct Action and the RET are in conflict. Direct Action is designed to achieve specified reductions at lowest cost. In contrast, the RET must achieve a specified amount of electricity to be generated by renewable energy irrespective of how much CO2 it avoids and irrespective of cost.

Why do we need a RET as well as Direct Action? Why not allow Direct Action to do its job, to achieve emissions reductions at the lowest cost? Why distort the electricity market with mandated renewable energy requirements?

The RET should be either repealed or closed to new entrants with existing and committed projects incorporated in the Direct Action scheme. The Direct Action scheme should be renamed 'CO2 Emissions Reduction Scheme' (CO2 ERS). The CO2 ERS should be technology neutral, i.e. it must not distort the market by favouring any one type or grouping of technologies. The scheme's name should be honest, objective and correctly state its purpose.

6 Recommendations

In consideration of the issues outlined above, I recommend that:

1. The Government task an appropriately qualified agency, such as the Productivity Commission and/or BREE with estimating the full economic cost of wind energy per MWh and the CO2 abatement cost ($/t CO2 avoided).

2. To get an early indication, contract an appropriately qualified consultant (such as ACIL-Allen) to:

    a. assemble the best estimates it can of the ‘high quality’ data required for the sophisticated analysis (this may include seeking information from generators with appropriate ‘commercial in confidence’ agreements), and

    b. estimate the CO2 abatement cost with wind power (including all the hidden costs and effects of higher electricity costs on the Australian economy).

3. Either, repeal the RET legislation which will:

    a. avoid what will become an escalating compliance cost of emissions monitoring if it remains in place, and

    b. allow Direct Action to operate without the RET being a major market distortion.

4. Or, if repeal of RET is not politically acceptable, close the RET to new entrants and incorporate the existing and committed RET installations into Direct Action.

5. Change the name of Direct Action to ‘CO2e Emissions Reduction Scheme’ (CO2e ERS). This should be technologically neutral with the primary selection criteria being objectively justifiable CO2e avoidance cost (i.e. $/t CO2e avoided).

7 Responses to the Terms of Reference items

7.1 a. Household power prices

“a. the effect on household power prices, particularly households which receive no benefit from rooftop solar panels, and the merits of consumer subsidies for operators;”

The Levelised Cost of Electricity (LCOE) from wind turbines is around four times higher than the baseload power plants it is intended to displace ($130/MWh v $30/MWh, see Table 3). Clearly, the impact of wind turbines on power prices is substantial. Consider wind generation at 15% of the total, which is likely by 2020 under the existing RET, then 15% of our electricity would cost four times that from current baseload plants, i.e., an average increase of 45% in wholesale prices. This could mean a real increase in retail prices of around 20%.

7.2 b. Clean Energy Regulator

"b. how effective the Clean Energy Regulator is in performing its legislative; responsibilities and whether there is a need to broaden those responsibilities"

The CER does not collect the information needed to accurately estimate the emissions avoided by intermittent generators such as wind turbines and solar panels.

However, I do not recommend that the CER regulations be broadened to require power stations to provide emissions estimates at 30 minute intervals because doing so would lead to escalating compliance costs of emissions monitoring forever. Although monitoring emissions from power stations is a requirement in EU and USA and is not hugely costly, the issue is that it will lead to ever increasing compliance costs for other emitters that are much more difficult to monitor. This can be seen from the example of the paint factory in NSW (Appendix 4). This is a slippery slope. Where do we stop before we have every farmer monitoring emissions from every cow, sheep and goat?

There is an alternative way to cut emissions from electricity without the need for emissions monitoring – France's emissions intensity of electricity is 10% of Australia's, its electricity is near the cheapest in EU, and they've been doing it for over 30 years (i.e. before 'carbon' restraint policies were introduced).

I do not recommend tightening the regulations for emissions monitoring. But if we continue with the RET mandating renewable energy, then it will inevitably become a requirement in order to estimate the cost of emissions avoided by wind and solar. This is just one example of how regulations and compliance costs will be ratcheted up over time if we continue with policies like the RET (and/or carbon pricing).

7.3 h. Energy & emission I/O equations

"h. the energy and emission input and output equations from whole-of-life operation of wind turbines;"

Wind power is less effective at avoiding emissions than commonly assumed in analyses of emissions avoided and cost per tonne avoided. Furthermore, the effectiveness decreases as the proportion of wind generation increases. Examples:

- Wind generation in ERCOT (Texas) was 79% effective in 2007-09 (Kaffine *et. al.*, 2013) at 4.7% wind proportion of generation (c.f. 2.9% in Australia in 2012-13).
- Wind generation in EirGrid (Ireland) was 53% effective (Wheatley, 2013) at 17% wind proportion of electricity (i.e., similar to wind proportion expected in the NEM by 2020 if the RET remains as currently legislated).

Without the high quality emissions data from power stations, we may assume that wind generation in Australia is about 80% effective now and may approach 53% effective by 2020. At 50% effective the cost per tonne CO2 avoided would be twice the estimates that do not take effectiveness into account.

7.4 *i. Related matters*

"i. any related matter."

At 53% effective, the cost per tonne CO2 avoided would be nearly twice the estimates that do not take effectiveness into account. Economic analyses submitted to the 2014 RET Review estimated abatement cost of the LRET, which is mostly wind generation, at \$32-\$72/t CO2. These analyses may not have taken the effectiveness of wind generation fully into account; therefore, these analyses may have underestimated the abatement cost with wind turbines. If these analyses do not take effectiveness into account, and if effectiveness decreases to 53% by 2020, the estimates of abatement cost under the LRET would nearly double to \$60-\$136/t CO2 with effectiveness included.

To put the estimated CO2 abatement costs mentioned above in context, the 'carbon' tax was \$24.15/tonne when it was rejected by the voters at the 2013 Federal election. The current price of EU ETS carbon credits and international carbon credit futures are:

European Union Allowance (EUA) market price (10/3/2015) = €6.83/tCO2 (A\$9.50)

Certified Emissions Reduction (CER) futures price (9/3/2015) = €0.40/tCO2 (A\$0.56)

Therefore, the LRET in 2020 could be 2 to 5 times the carbon tax which was rejected by the electorate in 2013; 6 to14 times the current price of the EUA; and more than 100 times the price of CER futures out to 2020.

Clearly, the RET is a very high cost way to avoid GHG emissions. The rational decision is to close the RET to future investments. Or, as an interim measure, wind the target back to a real 20% of electricity generation.

8 References

AEMC, 2014, *RET Review Analysis* prepared by Frontier Economics

AEMO, 2014, *Fuel and Technology Cost Review – Report (ACIL Allen), 12 June 2014*

BREE *Australian Energy Technology Assessment* (AETA), 2012 and 2013 Model Update

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Herbert Inhaber, 2011, *Why wind power does not deliver the expected emissions reduction*

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Sustainable Energy Authority of Ireland (SEAI), 2014, *Quantifying Ireland's Fuel and CO2 emissions Savings from Renewable Electricity in 2012*

UARG, 2014, *Comments on the US EPA 'Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units; Proposed Rule'*

US EPA, 2009, *ECMPS Reporting Instructions - Emissions*

US EPA, 2009, *Plain English Guide to the Part 75 Rule*

Joseph Wheatley, 2012, *Quantifying CO2 savings from wind power* (Version submitted to journal prior to peer review, no paywall)

Joseph Wheatley, 2013, *Quantifying CO2 savings from wind power*

Appendix 1: '*Quantifying CO2 savings from wind power*'

Below are excerpts of the Outline and Conclusions of Wheatley, 2012, '*Quantifying CO2 savings from wind power*' in Ireland (these excerpts are from the paper as submitted to the journal, not the published version, because the submitted version contains several points of relevance to this submission that are not included in the published version). This analysis is an example of what needs to be done to get a reasonable estimate of the effectiveness of wind turbines at avoiding CO2 emissions. The first take-away message is that CO2 avoided is likely to be less than commonly believed. (Therefore, the cost per tonne CO2 avoided is higher than commonly recognised.) The second take-away message is that Wheatley's analysis using high quality data gave a significantly lower effectiveness than his preliminary, simple analysis using the data published by the Irish grid operator.

[My emphasis added in **bold**]

1 Outline

This communication describes a straightforward data-mining approach to the problem of quantifying emissions savings when wind power generation is used to displace fossil fuel based electricity generation. Using high-quality data from the Irish electricity grid in 2011, it is shown **that emissions savings were considerably lower than grid average emissions intensity**.

Increase in atmospheric greenhouse gases, due mainly to burning of hydrocarbons and coal, is shifting the Earth's radiative balance in favour of a warmer climate.[1] Reduction of industrial CO2 emissions is a major focus of global environmental policy.[2] One widely adopted policy measure are state supports for wind power[3] on the grounds that wind generation displaces fossil fuel generation and therefore reduces emissions. Generous state supports have included mandatory targets, feed-in tariffs, subsidised finance for infrastructure etc. As a consequence, significant amounts of wind power have been embedded into electrothermal generation systems. On the other hand, it is known that thermal generation responds in a non-trivial way when operated in parallel to stochastic power sources to meet system demand. Not all thermal plant are displaced equally, with flexible and/or high marginal cost generation being displaced the most. Average efficiency is reduced and higher cycling rates occur than would otherwise be the case. These effects tend to reduce the effectiveness of wind power in meeting it's primary policy goal, namely emissions reduction.

The task of quantifying emissions savings from wind power is not straightforward. Electricity grids are complex systems, with many competing components and feedbacks. Moreover each system has a unique combination of fuel-mix, generator types, wind penetration, interconnection, despatch practices etc. Estimates of emissions savings have ranged widely[4] from higher than grid average[5, 6] to near zero[7, 8]. Savings assumptions by public authorities have trended lower over time.[9] **Meanwhile despatch models have demonstrated that marginal savings decrease as installed wind capacity increases[10, 11] and that high levels of wind penetration may even be counterproductive in terms of emissions**.[12]

Empirical approaches based on real world grid data can help shed further light on these issues. Ireland in 2011 is a good empirical test case for the following reasons:

1. high average wind penetration (17% in 2011)

2. minimal electricity exports meant that virtually all wind generation was accommodated on the domestic grid in 2011

3. modern thermal plant portfolio with large amounts of relatively flexible gas generation (≈ 58% of demand) as well as coal and peat plant

4. zero nuclear and a low level of hydro (≈ 2%)

5. highly volatility of wind generation helps statistical analysis over relatively short timeframes such as one year

6. availability of relatively high frequency grid data and mandatory emissions reporting at plant level under EU-ETS.[13]

The Irish grid operator[14] reports approximate system demand, wind generation and total CO2 emissions rate every ¼ -hour. It is easy to obtain **a preliminary estimate of emissions savings** from this dataset. Linear regression of the time-series of grid carbon intensity (emissions rate per unit demand) onto wind penetration (wind generation per unit demand) gives a zero-wind emissions intensity of 0.54tCO2/MWh[6] and wind power savings 0.35tCO2/MWh in 2011. This is equivalent to a **displacement effectiveness of just 59%**[7]. A plausible interpretation is that wind power displaces primarily clean gas (which have typical emissions ≈ 0.35tCO2/MWh) rather than high emissions coal or peat.

While these numbers are suggestive, their origin and accuracy are unclear. Firstly, aggregate numbers cannot show which generators or fuels are being displaced by wind power. Secondly, cycling effects (startup and ramping of thermal plant) are not included in the carbon emissions algorithm used by the grid operator. Thirdly, the role played by interconnection (electricity imports and exports) is unclear. Fourthly, the result for emissions savings is sensitive to

---

[6] 54t CO2/MWh is updated to agree with the value in the peer reviewed version published in *Energy Policy*. The value in the version submitted to the journal was 51 t CO2/MWh.
[7] 59% is updated to agree with the value in version published in *Energy Policy* . The value was 65% in the version submitted to the journal.

the correlation between wind generation and system demand. Spurious correlation may be present because the estimate of total wind generation is also used in the calculation of system demand.

In this study, time-series of CO_2 emissions are estimated for each gridconnected thermal unit in 2011. This calculation is based on generation data and physical characteristics of each generator. Additional emissions due to startups are included. Based on this CO_2 data, and a careful treatment of the wind and system demand, we estimate wind savings of -0.28tCO_2/MWh with implied **effectiveness of only 53%**. Some implications of these numbers are discussed at the end of the article.

4 Conclusion

As currently deployed, wind power is a supplementary power source whose role is to displace fossil-fuel generation. Ireland is a typical case where rapidly growing wind penetration is embedded in a diverse portfolio of thermal plant. A detailed empirical model of operational CO_2 savings was developed for 2011. It is found that savings of 0.28tCO_2/MWh were achieved, versus a zero-wind emissions intensity of 0.53tCO_2/MWh. **This estimate is at the lower end of expectations**.[10] Notably, it is significantly lower than the emissions intensity of CCGT plant which play the primary role in balancing wind generation. **There is evidence that effectiveness is likely to fall further as wind penetration increases**.[11, 12]

Assessments of the economic or environmental benefit of wind power are not credible unless they are based on accurate emissions (and fuel) savings. This study suggests that savings are lower than have been contemplated by public agencies to date. In particular, the Irish government has an ambitious target of meeting 37% of domestic electricity demand using wind power by 2020. **It is of concern that at 17% wind penetration, the system is already in a regime where effectiveness is approaching ≈ 50%, even before significant curtailment and/or exports of wind power begin to occur.**

Finally, life-cycle estimates of CO_2 emissions involved in construction and installation of wind power are sensitive to assumptions about the capacity factor, economic life of wind turbines, infrastructure requirement etc.[20] Estimates are in the range 0.002-0.08 tCO_2/MWh. At the upper end of this range, life-cycle emissions form a significant fraction of operational CO_2 savings.

Appendix 2 – Ramp rates and heat rate curves

There is a widely held belief that the coal plants' fuel consumption rates do not change much during ramping and cycling. This is a misunderstanding. In most cases but not all, their rate of fuel consumption during ramping changes nearly in proportion to the electricity generated. According to this modelling study by the Sustainable Energy Authority of Ireland (SEAI) fuel consumption during cycling is only about 1% of total fuel used by thermal power plants in Ireland; the report is a response to the Wheatley analysis.

Ramp Rates

AEMO gives information about the ramp rates of all the NEM's power stations here: Ramp rates (Ref. sheet 'Existing Generators, Columns 0 to R). It also gives the annual average thermal efficiency and emission factors for each power station.

Example ramp rates (from AEMO):

Station	Ramp Up Rate (MW/h) - for start up	Ramp Up Rate (MW/h) - when running normally	Ramp Down Rate (MW/h) - for shut down	Ramp Down Rate (MW/h) - when running normally	Thermal Efficiency (%, HHV sent-out)
Bayswater	120	310	100	230	35.9
Eraring	150	300	210	300	35.4
Loy Yang A	350	330	430	320	27.2
Hazelwood	120	120	120	120	22.0

Heat rate curves

Below are some example heat rate curves for US black coal and brown coal plants.

Note that the US and Canada use the term 'heat rate' whereas in UK and Australia the term 'thermal efficiency' is more commonly used. Thermal efficiency is the reciprocal of heat rate with unit conversion so that numerator and denominator are in the same units.

Thermal efficiency = 3.6 / heat rate
Where heat rate is measured in MJ/kWh, GJ/MWh or TJ/GWh.

If the charts below were plotted as thermal efficiency instead of heat rate, they would be rotated 180 degrees (top to bottom), i.e. start low on the left, rise rapidly then flatten.

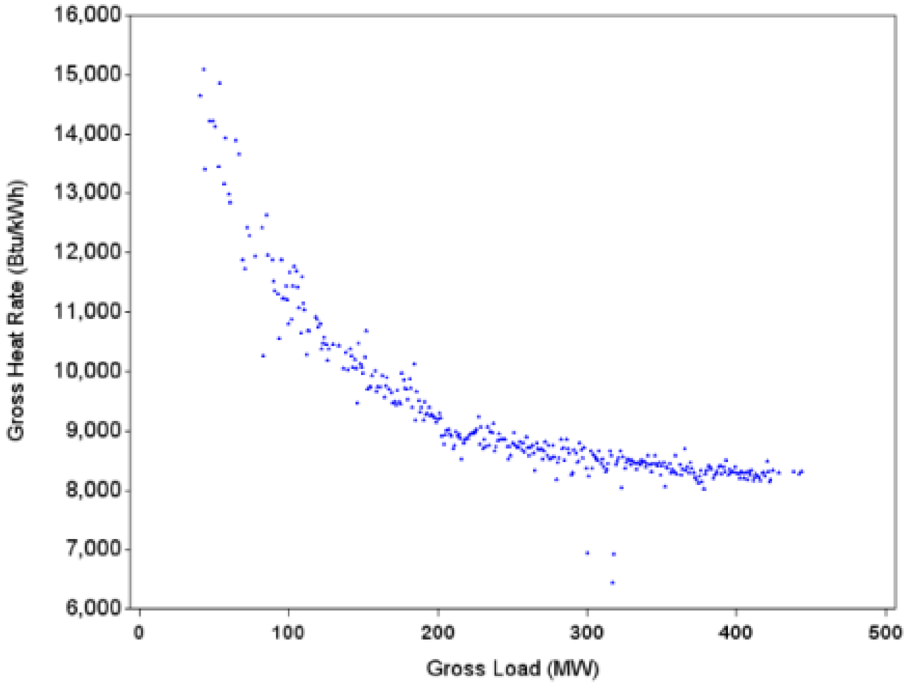


Figure 2-1. Gross Heat Rate vs. Load (MW): Indian River Unit 4 (Bituminous, Subcritical Opposed-fired Boiler)

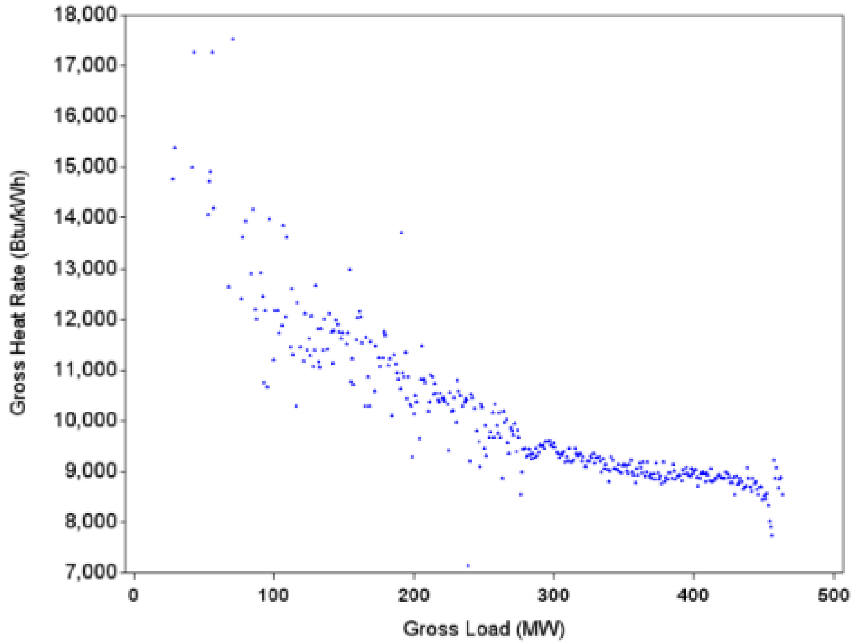


Figure 2-2. Gross Heat Rate vs. Load (MW): Springerville Unit 4 (Subbituminous, Subcritical Wall-fired Boiler)

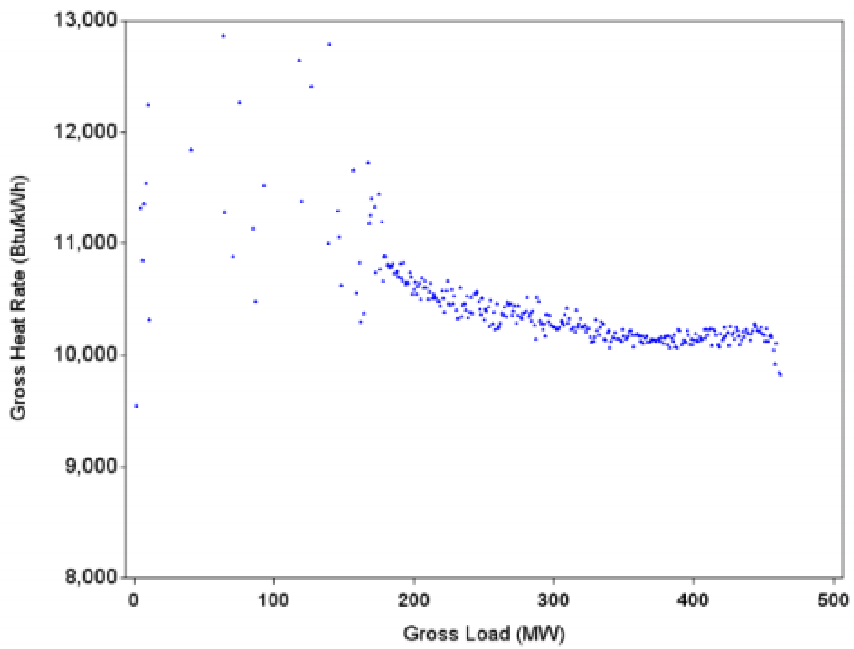


Figure 2-3. Gross Heat Rate vs. Load (MW): EW Brown Unit 3 (Bituminous, Subcritical Tangential-fired)

Source: [UARG (2014) Comments on the US EPA 'CARBON POLLUTION EMISSION GUIDELINES FOR EXISTING STATIONARY SOURCES: ELECTRIC UTILITY GENERATING UNITS; PROPOSED RULE']

Appendix 3 – Simple calculation of CO2 abatement cost ($/t CO2 avoided)

Calculation method:

From Table 1 (page 24):
Average LCOE of electricity from *existing* baseload generators (the intended target for wind turbines to force out of business) = $30/MWh
The average LCOE of new wind turbines = $110/MWh
Therefore, increase in costs due to replacing *existing* baseload generators with *new* wind turbines = $80/MWh

From Table 1 (page 24):
CO2 emissions intensity of *existing* baseload generators = 1 t CO2/MWh
CO2 emissions intensity of wind turbines = 0 t CO2/MWh
Therefore, CO2 savings achieved by replacing baseload generators with wind turbines if wind turbines were 100% effective = 1.0 t CO2/MWh
It follows that CO2 savings achieved by replacing baseload generators with wind turbines if wind turbines were 50% effective = 0.5 t CO2/MWh

Abatement cost is calculated as LCOE increase divided by Emissions Intensity savings.
At **100% effective,** abatement cost = ($80/MWh) / (1.0 t CO2/MWh) = **$80/t CO2**
At **50% effective,** abatement cost = ($80/MWh) / 0.5 t CO2/MWh = **$160/t CO2**

Table 3 below shows inputs, intermediate calculation results and the abatement cost at 100%, 80% and 53% effectiveness. The columns show the results for three cases, assuming wind displaces coal, gas or the NEM avg. The inputs are nominal values (from Table 1) for the purpose of illustrating this simple method to estimate abatement cost.

Table 3:

Inputs and Assumptions

	Coal	Gas	NEM avg.	Wind
LCOE, $/MWh	$30	$80	$50	$110
CO2 EI, t CO2/MWh	1.0	0.5	0.9	0.0
Wind substitutes for:	Coal	Gas	NEM avg	
LCOE increase, $/MWh	$80	$30	$60	
CO2 EI savings, t CO2/MWh	-1.0	-0.5	-0.9	

CO2 abatement cost ($/t CO2 avoided)

	Wind substitutes for:		
Effectiveness	Coal	Gas	NEM avg.
100%	$80	$60	$67
80%	$100	$75	$83
53%	$151	$113	$126

Other estimates of CO2 abatement cost with the RET

This section includes CO2 abatement cost estimates from other sources for comparison. However the various estimates use different assumptions. Important differences from the estimates shown in Figures 2 are:

- The abatement costs in Figures 2 and 3 are calculated from the inputs in Table 1 which in turn are nominal values based on BREE AETA 2012 and 2013 Update. I've assumed no change in real LCOE to 2020. ACIL-Allen uses projected costs for the period 2014 to 2030 and to 2040. The abatement cost estimates would have very high uncertainty, but it is not quantified.

- The decreasing CO2 effectiveness as the proportion of wind generation increases is not taken into account.

- Some of the other costs that should be attributed to wind generation (see Section 4.2) may not be taken into account (Figure 3 includes an allowance for these additional costs).

Source	Applies to	year	$/t CO2	Reference
This Submission, Figure 2, 100% effective, NEM avg.	Wind	2012	67	Figure 2
RET Review Report, ACIL-Allen report	LRET	2014 to 2030	62	Table 3, p42
Frontier Economics	RET		55-65	RET review p42
Deloitte	LGC only	2013	72	p20
Productivity Commission	LRET	2009-10	37-111	Appendix 3
AIGN, 2013, RET How it works and what it costs		2012	109	Table 3.4, p13
MIT CEEPR, 2013 - The Cost of Abating CO2 Emissions by Renewable Energy Incentives in Germany	Wind	2010	90	p14

The following is an excerpt from p42 of the [RET Review Report](), 2014:

ACIL Allen's estimates for the cost of abatement of the RET are summarised in Table 3. The cost of abatement of the current RET policy is estimated to be $35 to $68 per tonne over the period 2014 to 2030, with the SRES being higher than the LRET at $95 to $175 per tonne in comparison with $32 to $62 per tonne to 2030.

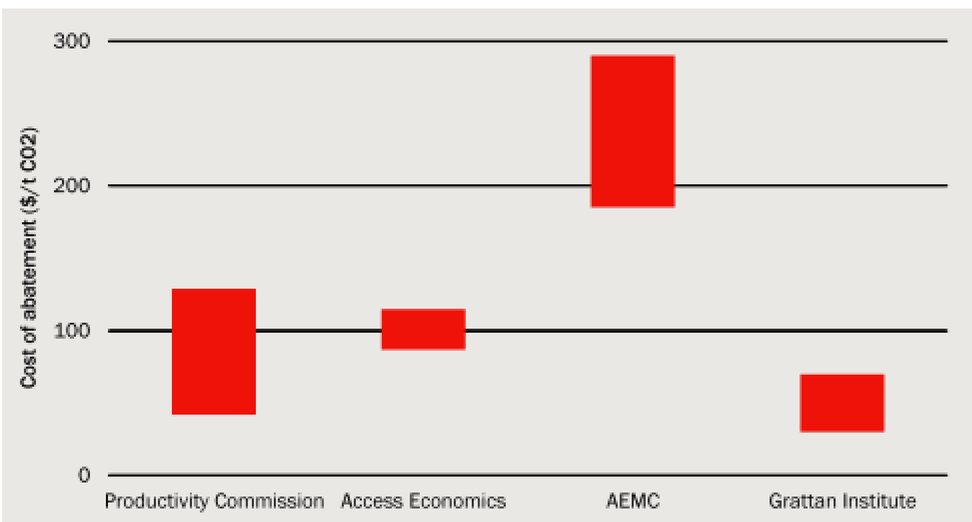
Table 3 ACIL Allen estimates of the cost of abatement of the RET ($/t CO_2-e)

	2014 to 2030			2014 to 2040		
	RET	LRET	SRES	RET	LRET	SRES
Undiscounted	**35**	**32**	**95**	**25**	**22**	**79**
Discounted	**68**	**62**	**175**	**62**	**56**	**185**

Similar cost of abatement estimates have recently been made elsewhere. Modelling by Frontier Economics estimates that the cost of abatement from the RET is between $55 and $65 per tonne.[41] Modelling by Deloitte estimates the cost of abatement (based on LGC costs alone) of the RET to be $72 per tonne in 2020, increasing to $82 per tonne in 2030.[42]

The following charts, table and text are excerpts from AIGN, 2013, *RET How it works and what it costs*:

3.6Ranges for the cost of abatement under the overall RET scheme



3.7 Comparison of the cost of abatement under the RET

	Productivity Commission (2011)	Access Economics (2011)	AEMC (2011)	Grattan Institute (2011)
Measure of cost of abatement	Implicit abatement subsidy[3]	Cost of purchasing RECs divided by total emissions abatement achieved	Cost relative to change in emissions[4]	Cost of complying with scheme relative to abatement achieved
Relevant year(s)	2009-10	2020	2011-2020[5]	2010
Cost/subsidy equivalent under LRET scheme (A$m)	283-459	n/a	320-495	
Abatement under LRET	4.1-7.6 Mt CO_2	n/a	4.0-9.0 Mt CO2-e	8.6 Mt CO_2-e
LRET cost of abatement ($/t CO_2)	37-111	n/a	55-80	
Cost/subsidy equivalent under SRES scheme (A$m)	52-98	n/a	50-750	
Abatement under SRES	0.2-0.3 Mt CO_2	n/a	0.1-2.5 Mt CO_2-e	0.2 Mt CO_2-e
SRES cost of abatement ($/t CO_2)	152-525	n/a	300-500	
Cost/subsidy equivalent under overall RET (A$m)	335-556	3,944-3,982[6]	n/a	
Abatement under RET	4.3-8.0 Mt CO_2	34.6- 45.3 Mt CO_2-e	4.1-11.5 Mt CO_2-e	8.8 Mt CO_2-e
Overall RET cost of abatement ($/t CO_2)	42-129	87-115	185-290[7]	30-70

Source: As shown in column headings

A number of important points emerge from these comparisons:
■ the overall RET cost of abatement ranges from $30 to $290 per tonne of CO2
■ the cost of the LRET is lower, ranging from $37 to $111 per tonne of CO2
■ the cost of the SRES is considerably higher, ranging from $152 to $525 per tonne of CO2
■ each of these costs is higher than either the current or expected carbon price. The presence of the RET therefore raises the cost of abatement to the Australian economy as a whole.

Looking at the individual studies:
■ Access Economics report on the impact of climate change policies estimates that abatement cost under the RET is approximately $87-115/t CO2-e at 2020
■ The Productivity Commission also evaluated the 'effective' carbon price or the cost of reducing greenhouse gas emissions of different carbon emission policies. The commission estimated that the cost of abatement under the RET scheme was in the range of $42-$129 in 2009 and 2010. Although the study does not explicitly estimate the cost of the LRET and the SRES, it does measure the cost of abatement under the large-scale and small-scale component of the RET as it existed in 2010
■ The relatively lower cost of abatement estimated by the Grattan Institute is based on certificate prices. The cost per tonne of CO2-e abated has ranged from $30-$40/t CO2- e when certificate prices have been low (reached as low as $15 near 2007) to around $70/t CO2-e when certificate prices have been high (reached a peak of $50 in 2008/09). The

price of certificates collapsed by 2005 when the scheme was substantially over supplied with renewable energy and revived soon after 2007 when policy commitments were made to expand the target (Grattan Institute 2011)

■ The cost of abatement for the overall RET scheme estimated by the Australian Energy Market Commission (AEMC) is significantly higher than other estimates. Importantly, the cost of abatement under the LRET estimated by the AEMC is in a similar range to that evaluated by the Productivity Commission, despite the use of entirely different approaches. However, as the AEMC takes an average of the abatement cost under the LRET and the SRES to estimate the cost of abatement under the overall enhanced RET, it is obvious that the SRES component of the RET is driving up abatement costs significantly

■ As AEMC note, estimating the cost of abatement under the SRES or other policies such as jurisdictional FiTs which support solar PV installations is difficult as it is not possible to entirely disaggregate the abatement or the cost that should be attributed to one particular policy. For this reason, the costs of abatement under the SRES have been based on the costs of abatement from solar PV installations, which reflect the cost premium borne by the economy as a whole when replacing solar PV with gridbased electricity (AEMC 2011). In this way, the cost of abatement is measured by the economic resource cost of PV installations divided by the abatement these installations manage to achieve. The costs range from around \$500/ tonne CO2-e in 2010-11 to around \$300/ tonne CO2-e in 2019-20, highlighting that solar PV offers a relatively expensive means of achieving abatement. The high cost associated with the SRES therefore translates to a relatively high average cost of abatement under the overall enhanced RET scheme.

References:

ACIL-Allen, 2014 *RET Review Modelling*

CIE for AIGN, 2013, *RET How it works and what it costs*

Deloitte, 2014, *assessing the impact of the renewable energy target*

DPMC, 2014, *RET Review Report*, Section 5.6, Table 3

Frontier Economics for AEMC, 2014, *RET Review Analysis*

Productivity Commission, 2011, *Carbon Emissions Policies in Key Economies*

MIT CEEPR, 2013, *The Cost of Abating CO2 Emissions by Renewable Energy Incentives in Germany*

Appendix 4: – Compliance costs of GHG emissions monitoring – a NSW paint factory's experience

Below are copies of some interesting comments by engineer 'Graeme No.3' on 'The ultimate compliance cost of the ETS'. Some of his comments are copied below. Consider how much higher the cost per tonne CO2 avoided would become as the requirements inevitably will be ratcheted up to require GHG emissions monitoring from smaller and smaller emitters. Consider this as an indication of the effect on medium and small businesses as requirements would inevitably be ratcheted up over time.

Extracts of four comments by Graeme No 3 here:

> "Estimates of emissions from the combustion of individual fuel types are made by multiplying a (physical) quantity of fuel combusted ... and a fuel-specific emission factor
>
> I've retired from all that estimation but was involved when it started in NSW when I worked for a paint Company making some resins. The short answer is that we didn't know what specific fuel types or amounts were combusted in our after burner (to reduce all emissions to CO2 and some nitrogen oxides).
>
> Firstly, a portion of the resin ingredients were chemically changed during reaction, and a mixture of the reactants and the changed substances went straight to the oil fired after burner. It was a complex and variable mixture, and analysing each reaction would have been a nightmare of complexity.
> Also into the afterburner went volatiles from the paint production. As there were over 6,000 products and hundreds of volatile ingredients it was impossible to calculate emissions.
>
> The 4 "methods" put forward by the public servants ranged from idiotic to bizarre. (No-one in the paint industry could supply the answer, but were threatened with fines if they didn't).
>
> I moved on, thankfully, and my successor was a practical (unscrupulous) fellow who responded by generating a vast spread sheet of over 600MB. 16 pages of calculations, I've forgotten how many pages of information on composition, tonnage produced, batch sizes and frequency of manufacture. All in 10 point Arial font with no graphics. Factors were assumed and buried in obscure corners with no explanations.
>
> One resin might be spread over 200 products. And with 6000 rows and 120 columns on a page, try following through that, esp. with references from page to page to another page. It looked impressive, but trying to check it was nigh on impossible, but the public servants were pleased and even recommended that other paint companies consult him! His view was that he retired in 5 years and

they wouldn't figure it out in that time. His comment was "Brains baffle b*llsh*t".

This I add happened more than 5 years ago."
Posted by **Graeme No.3**, Thursday, 10 May 2012 5:54:18 PM"

"The CO_2 emissions from the after burner were, as first comment above, impossible to measure. Installing a spectrophotometer 70' up (as was suggested by the public servants) exposed to the weather and to 300ºC exhaust gases didn't appeal as reliable.
The point was that the highly variable flow of flammables from the resin plant and/or the paint factory was balanced by the oil firing to maintain the right temperature. Since we could only get an average figure for the oil consumption, and no figures at all for the flow of flammables, there was no way you could get the amount of CO_2 emitted.

The Government assumptions were from a paint plant with 2 bulk tanks (of water based resin) and 3 mixing tanks. They assumed that all paint companies were similar. We had over 200 tanks of varying sizes. Even the bulk holding tanks could hold different materials at different times of the year.

Also, we had over 6,000 products. Classed into categories of similar composition, and in groups of 20 to 200 (roughly). The public servants came to a meeting and faced with arguments that their 4 suggested methods wouldn't (and couldn't) work, suggested that we install recording spectrophotometers at suitable points in the paint factory. We estimated we would need 112 measuring heads, and the figures would have been worthless without simultaneous air flow measurements."
Posted by **Graeme No.3**, Friday, 11 May 2012 6:33:31 PM

All the other paint companies were in the same position. One of the public servants got very agitated and arrogant about the lack of response (so much so that complaints from other companies resulted in him being disciplined and removed).

As I said the two of us worked on it for solid weeks, then had 2 or 3 meetings with the public servants over about another 6 weeks. All up about 10 weeks work for nil result.

The new engineer took that different approach. I think it took him 5-6 weeks to prepare the spreadsheet, which I think had to be copied onto a DVD to give to them.

The public servants were delighted, they had numbers! Other paint companies got together with him, and prepared their own sets of figures. And I believe for some years these were up-dated annually (at a cost of 2 weeks work).
As I indicated the figures were quite dubious, but that didn't seem to matter. I have no doubt that figures like this were carefully integrated into their planning.

I don't believe that many companies can make accurate measurements of all the emissions which the public servants want. They seem to think that everything is measured as a matter of course, and that Companies employ lots of people to do that, regardless of cost.

Personally I think the cost of accurate measurements will be beyond most companies resources, and an approach like the above will be adopted. After all, the public servants won't be able to measure them anyway, even if they wanted to do so.
Posted by **Graeme No.3**, Friday, 11 May 2012 6:51:26 PM

Peter Lang,
curious how the old memories come back.

At the time it seemed a clash of cultures; there wanted something and couldn’t see why it wasn’t supplied a.s.a.p. The public servants weren’t interested in our difficulties, they expected us to drop everything and comply with their demands. Almost feudal, like a Baron addressing serfs.

The original demand came with a deadline, and threatened us with fines and/or imprisonment if we didn’t supply the information on time and guarantee its accuracy.

I don’t think that the question of the costs of compliance ever crossed the minds of this government or its advisors. For over 50 years the amount of paperwork they’ve demanded from industry has grown and grown. Each Department assumes their demands are reasonable and not much work (forgetting that collecting data takes far more time than filing it) and not allowing for other departments demands.

The howl from industry has been loud and clear for years, yet ignored. The burden is becoming too great, and will be resolved by either of two methods - that of the Israelites departing Egypt, or the French peasants revolting. For companies the first is in vogue.

That we might have other priorities wasn’t considered, but even then the firm was trimming staff. We were down about 40 from 4 years before, and had about 170-180 working there.

I lost contact but I know that there are now less than 50 there. Drastic cuts have been made because they are struggling to compete with overseas competitors, yet they were exporting quite large volumes when I was there.
Posted by **Graeme No.3**, Saturday, 12 May 2012 9:23:33 AM

Consider the consequences and costs of regulatory ratcheting if we increase the requirements for emissions monitoring. Consider the number and size of companies, charities, etc. that would eventually have to monitor and report their emissions as, progressively, the countries of the world join in emissions monitoring and eventually all have to monitor some 80% of all emissions in each country (Australia monitors 53% EU 45% and USA 49%). It's difficult to see how Australia could monitor 80% of all human caused emissions, let alone Eretria, Ethiopia, Mogadishu, Somalia, etc.

Therefore, I urge the Select Committee to strongly resist asking for an increase in regulatory burden of emissions monitoring. Consider where it will lead eventually if the world goes down this path. It's not necessary. Emissions from electricity can be largely avoided with now emissions monitoring – France's emissions from electricity are 10% of Australia's and that was achieved mostly during the 1970s and 1980s. That's the future, no need for emissions monitoring and no RET. Just Direct Action to buy the least cost GHG emissions abatement.