

Tricks and Traps in CO₂ Emission Impact Assessment

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Abstract

There are two distinct types of environmental impact arising from the use of fossil energy resources, local impacts of conventional pollutants and global impacts of CO₂. They have significantly different characteristics. The local environmental impacts are managed through the RMA process. CO₂ emissions can be minimised via energy efficiency and choice of energy source, but there is no national standard that can define an acceptable emission rate and CO₂ emissions are explicitly outside of the RMA process.

Therefore CO₂ emission impact assessment requires a different approach from that required to deal with conventional pollutants. The basic tool is an emissions inventory, based on a carbon balance. However the simple application of emission factors to fuel purchases can trap the unwary. The boundaries of the assessment must be cast wide to capture the bigger picture. Full Fuel Cycle analysis included emissions from fuel production whilst avoiding the imponderables in LCA analysis. Comparability between schemes requires translation into common basis of assessment, which is dollars per tonne of CO₂ emission avoided.

This paper examines some of the tricks and traps in CO₂ emission assessment work based on the authors experience in helping companies come to terms with the new paradigm of a carbon constrained world.

Introduction

Global Climate Change is the biggest and most challenging environmental problem facing the world today. Only the most ardent of climate sceptics would deny that there is a cause and effect relationship between the burning of fossil fuels and significant, probably adverse, changes to the global climate. Put simply, the case is now proven that the carbon that was laid down in fossil fuels over millions of years cannot be released into the atmosphere over tens of years without straining the adaptive capacity of the global ecosystem. However, there is great uncertainty surrounding the quantified relationship between fossil fuel use and adverse climate effect over time.

Defining the Assessment Basis

A large number of people would argue that until the adverse effect on global ecology can be compared on a consistent financial basis with the adverse effect on the global economy, then cost effective decisions cannot be made. The ideal basis for impact assessment of Greenhouse Gas emissions would be the **cost of marginal changes in global environmental consequences**. However, quantification of that measure falls firmly into the too-hard basket. Not only is there uncertainty in the climate change

mechanism, but also there is great variability in the global stage on which those changes are played out and, moreover, the time scale of change is much slower than is common human experience. We all know that changes are happening, but we can't quantify them or predict when they will become severe. What we do know is that when, with the benefit of hindsight, we have that detailed understanding it will be too late to avoid the environmental impact. Therefore the precautionary principle has been established.

As a way forward, faced with this dilemma, a more practical basis for uniform assessment of the impact of Climate Change has evolved, which is measured in **tonnes of CO₂-equivalent emission avoided**. The avoidance of the emission of a tonne of CO₂ is an action that can be quantified, and can be costed, and forms the basis of an evolving international accounting and trading system.

However, the avoidance of emission of a tonne of CO₂ is only a surrogate for the avoidance of adverse global environmental impact. It is not an end in itself but is an uncertain means to that end.

Carbon Trading

In particular, international trading in carbon abatement is evolving as a means of providing optimum benefit for least cost. Consequently a benchmark is evolving in the terms of dollars per tonne of CO₂ emission avoided, which currently stands at about NZ \$16 in Europe and is bound to rise¹. That "carbon price" is a measure of what might be practically done today to avoid CO₂ emissions. In no way does it relate directly to what would need to be done to avoid adverse global environmental impacts, nor to the revenue that needs to be raised to meet the costs of the environmental consequences of climate change.

A common misconception is that setting a carbon tax at the internationally traded price of CO₂ abatement will internalise the environmental externality of climate change. That line of thinking lays the trap of believing that business-as-usual activity can continue with just the going-price being paid to deal with the climate consequences. The purpose of fiscal measures is not to raise money to pay for consequences, but it is to provide a revenue neutral incentive for changes in behaviour and real movements away from business-as-usual. The challenge in emission avoidance impact assessment is to recognise and quantify changes from business as usual.

¹ Although this price is often referred to as the price of carbon, it is actually the price associated with a tonne of carbon dioxide equivalent emitted to the atmosphere, which actually contains 273 kg of carbon as the chemical element. Emissions of other greenhouse gases are converted to the CO₂-equivalent basis by using global warming potentials (GWP). For the duration of the Kyoto Protocol GWPs are fixed at 21 tonnes of CO₂ per tonne of methane emission and 310 tonnes of CO₂ per tonne of nitrous oxide emission, with higher values for specific organo-fluorine compounds.

Additionality

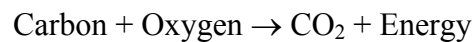
A key feature of assessment of emission avoidance is the concept of additionality. Emissions are only avoided when the change is additional to that which would occur anyway under a business-as usual scenario.

An example of this concept of “additionality” arose in connection with a project that I have recently been auditing for the Australian Greenhouse Office. The end use requirement was for process steam and the proponent correctly claimed that using a natural gas cogeneration scheme would generate less CO₂ than using coal fired boiler to meet that need. However, in the context of energy prices in that region, the gas option gave a better return on investment than the coal boiler option. Therefore the gas option was deemed to be the preferred business-as-usual option. Hence the gas option does not represent a deviation from business-as-usual and is not additional. On this basis, Government support for CO₂ emission abatement is not justified.

That case hinged on economic analysis, but most of the projects in which I have been involved depend on technical analysis. Therefore I will now focus on the technical assessment of CO₂ emission avoidance. In principle this depends on good carbon inventories based on an energy and element balance. That is the essential foundation for both cases being compared; i.e. the business-as-usual case and the CO₂ abatement case.

CO₂ is an unconventional pollutant

Conventional atmospheric pollutants are typically unwanted by-products of processes, which could, in theory, be eliminated without detracting from the primary purpose of the process. However, the simple chemistry of



means that CO₂ is an unavoidable direct consequence of getting energy from hydrocarbons. The discharges of other greenhouse gases are, in contrast, unintentional and potentially avoidable by-products of processes.

CO₂ has no direct local or regional environmental effects, except perhaps enhancement of plant photosynthesis, so it is not the cause of adverse environmental effects in normally experienced concentrations. Therefore dilution and dispersion, which is a means of avoiding adverse effects from conventional pollutants, is not applicable to CO₂ emissions. No national environmental standards have been promulgated for CO₂ concentrations in ambient air.

The adverse effects of CO₂ emission occur on a global basis and are unquantifiable. Therefore CO₂ emissions are explicitly excluded from New Zealand’s effects-based Resource Management Act.

CO₂ emission avoidance is a new paradigm outside of traditional experience.

CO₂ emissions from fuel combustion

CO₂ production from any fuel is directly proportional to the amount of energy released. It is therefore important to ensure that if fuel is actually measured by volume or weight or cost that the factors of conversion to an energy basis are carefully used. A common error in CO₂ emission assessments is to ignore the distinction between the theoretical higher heating value basis, commonly used for fuel sales, and the practical lower heating value commonly used for combustion engineering². This can lead to errors of about 10% for natural gas combustion and about 5% for coal combustion.

Energy purchase data is an accurate basis for GHG assessment when measured in gigajoules or kilowatt-hours but estimates based on the dollar price paid is frequently misleading.

Table 1 shows typical ranges of fossil fuel emission factors for use in compiling a greenhouse gas inventory. Emission factors outside of these ranges should be carefully questioned.

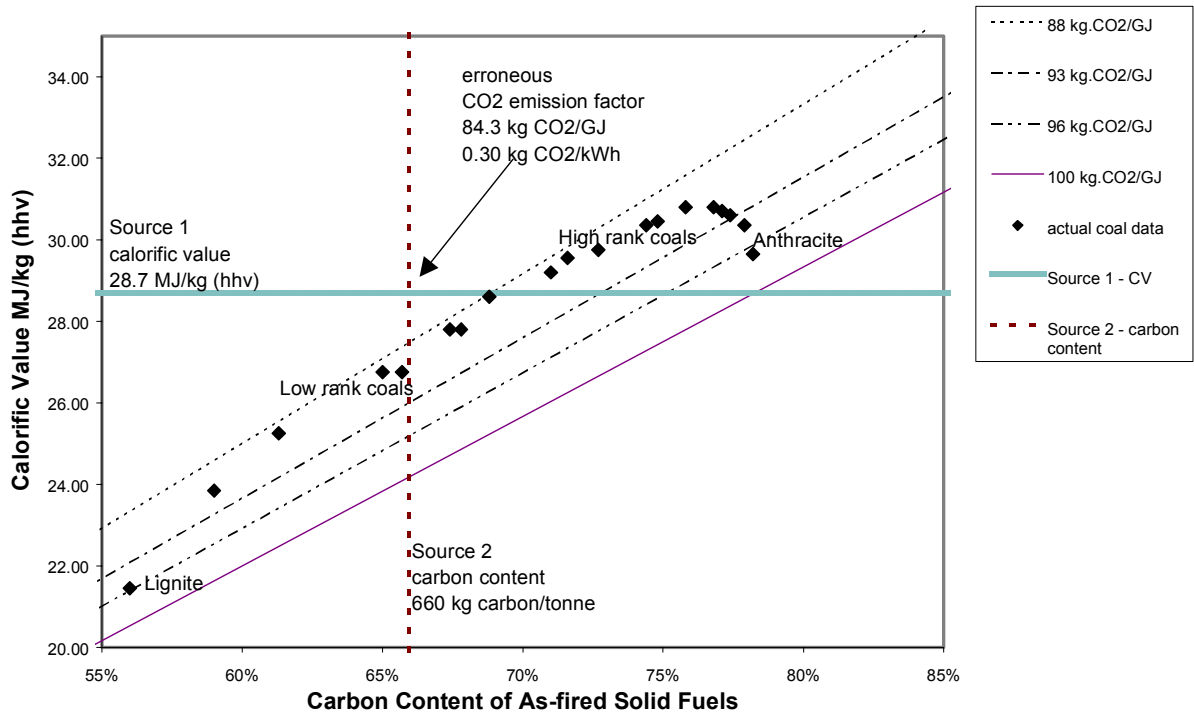
Table 1. Typical Fossil Fuel Emission Factors (higher heating value basis)

Fuel	kg.CO₂/GJ-hhv
Lignite	95-100
Coal	88-93
Heavy Oil	73-74
Light oil (inc. petrol & diesel)	69-70
LPG	59-61
Natural gas (<5% CO ₂)	50-55

Figure 1 is a chart showing energy based coal emission factors for a wide range of coals, which all fall within the range 88-93 kg CO₂ emission per gigajoule of energy release on the higher heating value basis. Also shown on this figure is how an incorrect (15% too low) emission factor might be derived by using inconsistent sources of data for defining the coal fuel.

² The higher heating value (gross calorific value) includes the latent heat of condensation of water vapour produced from the hydrogen content of the fuel. The lower heating value (net calorific value) does not include that latent heat, which can normally not be captured in a combustion system.

Coal emission factors



Chemical process emissions

In addition to combustion emissions CO₂ discharges to air from industrial processes are a significant source to be assessed in establishing a greenhouse gas emission inventory. An element balance of the overall process is the best way of ensuring accurate assessment.

Carbon in – Carbon out = Carbon discharged to air

Carbon discharged to air x 44/12 = CO₂ discharged to air

A top-down whole-of-site basis is more reliable for the CO₂ inventory than a bottom-up point source assessment. However, other greenhouse gases (CH₄, N₂O, fluorinated compounds) are best assessed on a bottom-up basis.

Process Emission Reduction Measures

Once a greenhouse gas inventory has been clearly defined, it often points the way to identifying practical measures for reducing emissions on the lines of these principles.

- Select inputs with lower carbon content (e.g. fuels)
- Increase carbon content of process outputs (e.g. carbonates)
- Reduce degradation of process materials to CO₂
- Improve energy utilisation efficiency
- Avoid unproductive energy use (e.g. standby)

- Treat other Greenhouse Gas emissions as conventional pollutants

Off-site emissions

In addition to the actual CO₂ emissions from sources on-site, an important aspect of greenhouse gas emissions are the consequential off-site emissions directly caused by the on-site demand for energy; both electricity and fossil fuels.

Electricity generation off-site is accounted for via a location-specific emission factors as illustrated by examples in Table 2.

Table 2. Examples of electricity emission factors for purchases

Region	kg.CO2/MWh
NZ average	120-200
NZ marginal	500-700
Victoria (brown coal)	1392
NSW, Queensland	1056
Tasmania	6

Electricity consumption avoidance has a higher emission factor than electricity production for export due to transmission losses

When refined fossil fuels are consumed, a consequential impact arises from the processing of primary energy resource to produce the market-ready product. Precombustion emissions arise from activities such as gas processing and compression, liquid fuel refining and pumping and coal mining and transport. A methodology for the assessment of these consequential emissions has been established called Full Fuel Cycle Analysis.

Full Fuel Cycle Analysis is a subset of Life Cycle Analysis, but does not include indirect consequences such as the creation of infrastructure.

Conclusions

1. Emission avoidance is a surrogate for environmental impact avoidance and must be “additional”.
2. Carbon taxes are intended as a measure to cause changes of behaviour. The payment of a carbon tax does not internalise the externality of climate change consequences. Nor should a carbon charge be considered as the cost of a license to continue with unsustainable business-as usual practices.
3. Greenhouse Gas emissions are unconventional pollutants.
4. CO₂ emissions are calculated from fuel use and energy and carbon balances.

5. Determination of fossil fuel emission factors on an energy basis are the key to accuracy.
6. Great care must be taken to ensure that source data and units are well defined.
7. Derived emission factors must be checked against a reliable source.
8. A Full Fuel Cycle Analysis approach is required for comparative studies of alternative routes to a product.