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The ranking of negative-cost emissions reduction measures

Simon Taylor*

School of Civil and Building Engineering, Loughborough University, Loughborough, LE11 3TU, UK

HIGHLIGHTS

- ► Marginal abatement cost curves (MACCs) are used to rank emission reduction measures.
- ► There is a flaw in the standard ranking method for negative-cost measures.
- ► Negative values of cost-effectiveness (in £/tC or equivalent) are invalid.
- ► There may be errors in published MACCs.
- ► A method based on Pareto principles provides an alternative ranking method.

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ABSTRACT

A flaw has been identified in the calculation of the cost-effectiveness in marginal abatement cost curves (MACCs). The problem affects "negative-cost" emissions reduction measures—those that produce a return on investment. The resulting ranking sometimes favours measures that produce low emissions savings and is therefore unreliable. The issue is important because incorrect ranking means a potential failure to achieve the best-value outcome. A simple mathematical analysis shows that not only is the standard cost-effectiveness calculation inadequate for ranking negative-cost measures, but there is no possible replacement that satisfies reasonable requirements. Furthermore, the concept of negative cost-effectiveness is found to be unsound and its use should be avoided. Among other things, this means that MACCs are unsuitable for ranking negative-cost measures. As a result, MACCs produced by a range of organizations including UK government departments may need to be revised. An alternative partial ranking method has been devised by making use of Pareto optimization. The outcome can be presented as a stacked bar chart that indicates both the preferred ordering and the total emissions saving available for each measure without specifying a cost-effectiveness.

1. Introduction

Marginal abatement cost curves (MACCs) are a common method of assessing the economics of measures to reduce emissions of greenhouse gases, particularly carbon dioxide. They first appeared about 20 years ago (Jackson and Roberts, 1989; Jackson, 1991; Mills et al., 1991; Sitnicki et al., 1991) as a variation on the energy conservation supply curves introduced by Meier (1982). In spite of some doubts about the behaviour of the calculations for negative costs (Wallis, 1992a, 1992b; Jackson, 1992, 1993), the use of such curves has become widespread in a variety of contexts. They have been applied to specific sectors such as non-domestic buildings (Pout, 2000), waste (Beaumont and Tinch, 2004; Hogg et al., 2008), transport (Spencer and Pittini, 2008), higher education (SQW Energy, 2009) and the National Health Service in England (Hazeldine et al., 2010). They have also been applied to whole countries, e.g., Denmark (Morthorst, 1994), the UK (Enviros Consulting Ltd, 2006; Toke and Taylor, 2007; DTI, 2007; CBI, 2007; CCC, 2008), and the USA (Creyts et al., 2007; Bloomberg, 2010). In addition, the McKinsey company (McKinsey, 2012) has produced MACCs for a large number of countries including Australia, Belgium, Brazil, China, Czech Republic, Germany, India, Israel, Poland, Russia, Sweden and Switzerland. MACCs have also been applied to non-CO_2 emissions (EPA, 2006), and their use recently extended to forming the basis for carbon pricing by the British government (DECC, 2009). Recent examples include their use in the British Government's Green Deal programme (DECC, 2011). Using the useful nomenclature of Kesicki (2010), the present work focuses on such "expert-based" curves which deal with individual measures, rather than "model-derived" ones. Kesicki and Strachan (2011) analysed some disadvantages relating to MACCs and pointed out that little academic work has been carried out on them. Kesicki and Ekins (2012) went further by calling for caution by policymakers in the use of MACCs.

* Tel.: +44 0 1509 228788.
E-mail address: s.c.taylor@lboro.ac.uk

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All methods of constructing these curves work in roughly the same way. Each emissions reduction measure is assigned two values: a figure of merit which indicates its cost-effectiveness in £/tC (tonne of carbon) or equivalent, and the total emissions reduction achievable over the period of interest. A rectangular block is plotted for each measure with height and width, respectively, corresponding to these values. The blocks are lined up from the smallest on the left to the largest on the right and the optimum outcome is obtained by implementing the measures in order from left to right. The total width of the blocks indicates the total emissions reductions achievable.

Some measures have negative costs, which means that their implementation results in a net profit over the period of interest. A typical example is domestic insulation which typically pays for itself within a few years. In such cases, the blocks extend below the *x*-axis and the most negative measure is taken to represent best value. So according to the MACC of Toke and Taylor (2007) in Fig. 1, the domestic lighting measure should be implemented first, followed by reduction of standby drain and so on.

On the face of it, it seems surprising that such negative-cost measures exist. One might expect that the availability of, effectively, something for nothing would cause the measures to be quickly taken up and the potential exhausted, leaving MACCs to deal only with positive costs. As Kesicki and Ekins (2012) put it, "This phenomenon… is not compatible with an efficient market." Explanations for this inertia include consumers' aversion to perceived debt and ability to cope with a limited amount of information at one time (DECC, 2011). In addition, Kesicki and Ekins' analysis of negative abatement costs concluded that the negative abatement potential is often overstated. The present work is not concerned with such arguments but simply with the treatment of negative abatement potential as it appears in the vast majority of published MACCs.

The cost-effectiveness of emissions reduction measures is also determined outside the framework of MACCs. For example, values of the cost-effectiveness of behavioural interventions were reported by Allcott and Mullainathan (2010) and calculations for transport measures were carried out by Kok et al. (2011).

The issue addressed in this paper is the validity of the standard figure of merit for cost-effectiveness, measured in £/tC or similar units and here denoted M_{std}, when the costs are negative.

The structure of the paper is as follows. Section 2 describes a serious problem with the standard way of calculating cost-effectiveness (which will be referred to as the standard metric or standard figure of merit) when applied to emissions-saving measures that make a return on investment. An analysis in Section 3, supported by a simple mathematical proof in Appendix A, shows that no metric satisfying reasonable requirements is possible for such measures. An alternative ranking method based on Pareto optimization is proposed in Section 4 and applied to some existing results in Section 5, revealing ranking errors by the standard metric. A discussion in Section 6 covers such issues as consequences for existing results and options for dealing with MACCs in the future. It also examines why the problem has not been addressed before now. Finally, conclusions are drawn in Section 7.

2. The problem

The standard figure of merit can be calculated in a variety of ways. The method used in the author's previous work (Toke and Taylor, 2007), following Jackson and Roberts (1989), was to determine the cost of the measure in £/MW h saved and divide by the mass of emissions per MW h saved. The cost was calculated as the net present value (NPV) of the measure using the same discount rate and period (5% and 15 years in this case) for all measures considered, and divided by the energy saved over the period of interest to give the required numerator. Equivalent methods, e.g., Bloomberg (2010), measure costs in \$/year and emissions savings in tC/year. It is convenient to assume for the present work that the normalizing value is energy saved, and to refer to the relevant quantities as specific costs (Blok et al., 1993) and specific emissions savings. So the standard metric can be described as

$$M_{std} = \frac{c}{g} \tag{1}$$

where c = specific cost and g = specific emissions saving.

The specific emissions saving g is always positive for the measures of interest, so when the specific cost c is positive, corresponding to a net financial loss, so is M_{std}. A smaller M_{std} is obtained from a lower specific cost or a larger specific emissions saving or both. Lower cost and higher emissions savings are both desirable objectives, so for positive costs the measure with the smallest M_{std} provides the smallest outlay per unit mass of emissions saved, and therefore the best value.

However, when the specific cost is negative (corresponding to a net return on investment, or profit), the picture changes. A smaller (i.e., more negative) M_{std} is achieved by a greater financial return, which is a desirable objective, or by a *reduction* in the specific emissions saving, the opposite of what is desired. This means that the measure with the lowest M_{std} is not necessarily the best option. More generally, it means that the ranking of a set of negative-cost measures, like that in Fig. 1, is not reliable. The problem is a serious one because an incorrect ranking means a potential failure to achieve the best-value outcome.

A simple example demonstrates the problem. Suppose there is a plan to install insulation in one or other of two identical houses, one heated by gas and the other by electricity. Insulation is simply a method of reducing heat loss, so the details, and in particular the capital and installation costs, are independent of the fuel. Now, for the purposes of illustration, suppose the cost of electricity is the same as that of gas. Then at current prices the NPV of the measure over a reasonable time period – say 15 years – will be positive (that is, there will be a net return) and the same for both houses. The amounts of heat saved over this period will also be equal, so the cost per unit energy saved, c, will be the same negative value in both cases.

The figure of merit M_{std} is c divided by the mass of emissions per unit energy saved, which in this case is simply the emissions

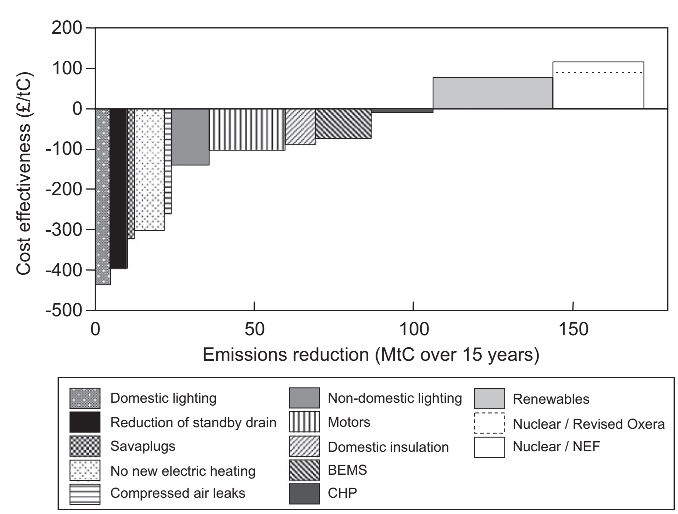

Fig. 1. MACC of Toke and Taylor (2007).