A Proposed Alternative Measure for Climate Change Potential

F. DeGroff

CCSF

Abstract

Carbon dioxide equivalents (CO_2e) is the current benchmark standard for expressing greenhouse gases equivalents and climate change potential, often the basis for carbon fees.

CO_2e is a one-dimensional scalar measure that does not account for carbon source or ultimate disposition, nor for either spatial or temporal shifts in carbon emissions. A carbon standard vector, however, would take both source and ultimate sink into consideration when calculating climate change potential.

We propose that climate change potential be measured using a logarithm temporal scale, named "carbon quality", abbreviated 'cq', of the form:

$$cq_{(carbon)} = f(\log 10\ [\text{mean carbon residence time}]_{(carbon)}).$$

The carbon quality vector measures when organic carbon from any carbon source is converted to CO_2 or to any lower energy organic carbon in any carbon reservoir, eliminating incentives for consumers to avoid carbon fees through temporal shifts in carbon emissions and spatial shifts via cross-border movement of embodied carbon.

Objectives

The purpose of this poster is to explore an alternative, comprehensive measure of climate change potential to the traditional measure of carbon dioxide equivalents.

Background

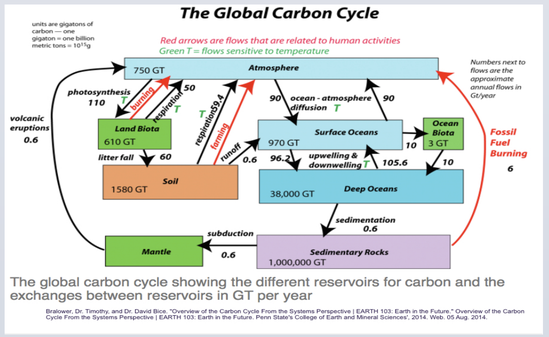
Carbon dioxide equivalents is the current benchmark standard for expressing climate change potential, expressed as CO_2e. According to the U.S. EPA,

> "The international standard practice is to express greenhouse gases in carbon dioxide (CO_2) equivalents, or CO_2e. Emissions of gases other than CO_2 are translated into CO_2 equivalents using global warming potentials."

The CO_2e standard is a proxy measure of climate change. The use of this standard, in one form or another as the basis for determining carbon fees, is limited by the one-dimensional, single-point nature of such a measure. The CO_2e standard makes no accommodation for the origin or source of the carbon, nor for alternative dispositions, and thus cannot account for either spatial or temporal shifts in carbon emissions.

Because the CO_2e standard is a scalar, one-dimensional measure of climate change, it has no directional component; it simply measures the equivalent quantity of CO_2 that is emitted into the atmosphere, with no regard for the source of carbon from which the emissions are derived.

> "Vector quantities have two characteristics, a magnitude and a direction. Scalar quantities have only a magnitude. When comparing two vector quantities of the same type, you have to compare both the magnitude and the direction. For scalars, you only have to compare the magnitude. When doing any mathematical operation on a vector quantity (like adding, subtracting, multiplying) you have to consider both the magnitude and the direction. This makes dealing with vector quantities a little more complicated than scalars." (Benson, 2014).



The global carbon cycle showing the different reservoirs for carbon and the exchanges between reservoirs in GT per year

Bralower, Dr. Timothy, and Dr. David Bice. "Overview of the Carbon Cycle From the Systems Perspective | EARTH 103: Earth in the Future." Overview of the Carbon Cycle From the Systems Perspective | EARTH 103: Earth in the Future. Penn State's College of Earth and Mineral Sciences', 2014. Web. 05 Aug. 2014.

Presumably, the underlying assumption for the CO_2e standard is that fossil fuels are the source of carbon. Such an assumption may be a reasonable approximation in a world where spatial or temporal shifts in carbon emissions (often referred to as 'leakage') are negligible, but such is not the case. Spatial shifts in carbon emissions to areas with no or lower carbon fees are already a significant portion of worldwide global emissions, and we expect that temporal shifts in carbon emissions, such as the conversion of carbon dioxide to biomass, will emerge and expand when and where carbon fees provide the incentive to do so.

Leakage

Carbon leakage is defined as:

> "the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries." (IPCC 2007)

We have an expanded view of carbon leakage which includes not only spatial displacement of carbon emission, as outlined by the IPCC, but temporal displacement of carbon emissions including emissions of organic carbon intended to avoid taxes on inorganic atmospheric carbon, as well as any method of carbon capture and sequestration intended to avoid taxes on emissions of carbon dioxide.

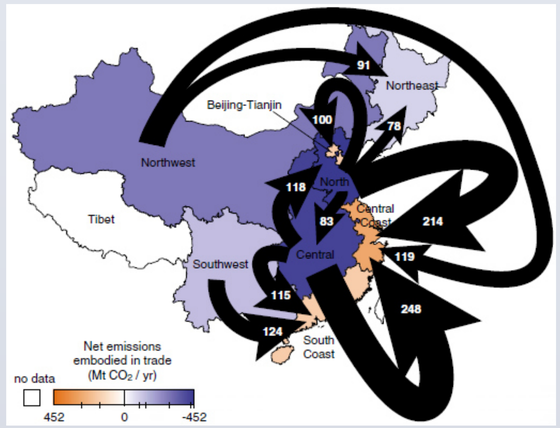
Numerous studies have highlighted the expanding scope of the spatial displacement form of carbon leakage, including:

> **"Embodied carbon flows are large and growing**
>
> Approximately 25% of all CO_2 emissions from human activities "flow" (i.e. are imported or exported) from one country to another." (Carbon Trust 2011)

and

> **"Embodied carbon imports are significant for many developed economies**
>
> Major developed economies are typically net importers of embodied carbon emissions. UK consumption emissions are 34% higher than production emissions: Germany (29%), Japan (19%) and the USA (13%) are also significant net importers of embodied emissions. For some economies with very carbon-efficient production processes, the relative importance of imported carbon is even greater. The high levels of net imports in France (43%) and Sweden (61%) reflect in part the low-carbon intensity of their energy systems." (Carbon Trust 2011)

There is even evidence of outsourcing of carbon emissions within countries such as China:



"… wealthy coastal provinces in China are now "outsourcing" a big chunk of their carbon pollution to the poorer inland provinces." (Plumer)

And there is evidence of increasing research into expanded forms of temporal displacement of carbon emissions such as the conversion of carbon dioxide emissions into algae:

Scripps and SoCalGas System to Use Algae to Capture Carbon Dioxide

July 30, 2012 | By Mario Aguilera
Science and Engineering SIO

Algae could absorb pollution emissions at the source



A new system will explore using algae to capture carbon.

Scripps Institution of Oceanography at UC San Diego (Scripps) and Southern California Gas Co. (SoCalGas) have entered into an agreement focusing on the design of an innovative system in which algae consume carbon dioxide (CO_2) emissions from natural gas combustion and cost-effectively convert it into valuable byproducts such as biomethane, biodiesel and animal feed.

For several years, researchers at Scripps, a member organization of the San Diego Center for Algae Biotechnology, and a number of commercial companies around San Diego and elsewhere, have been studying how algae can most efficiently be developed into a clean, renewable biofuel to one day replace non-renewable fossil fuels. Taking this research a step further, Scripps' researchers hope to leverage algae's natural ability to absorb CO_2 in the environment and convert it into oil rich biomass or biomethane or refined into fossil fuel replacements. After extracting the oils for biodiesel, the remaining biomass can be sold as a safe, protein-rich animal feed.

Reducing climate change without accounting for embodied carbon will be challenging as higher carbon prices increase the incentive to avoid taxes.

Proposal

We have no doubt that as the science and knowledge base of climate change increases, the need for a more robust measure and metric of climate change potential will become self evident. Advances in the methodology and data collection of climate change, along with improved understanding of the linkages between ecosystem services and human well-being, could well form the basis for an expanded, multi-dimensional metric for climate change potential in the future.

In the meantime, to develop a proforma accounting of the effect of spatial or temporal shifts in carbon emissions, we propose a carbon vector scale or metric as a proxy of climate change, one that, in contrast to the CO_2e standard, measures the change in residence time as carbon is moved or shifted between carbon reservoirs due to anthropogenic activity.

To best approximate the climate change effect, we propose that such a shift be measured using a logarithm scale, and the unit name be carbon quality, abbreviated as 'cq'. The general form of the equation is:

$$cq_{(carbon)} = f\ (\log 10\ [\text{mean carbon residence time}]_{(carbon)})$$

The carbon quality vector will measure the climate change when carbon, in any organic form from any carbon source, is converted to CO_2, or is converted to any lower energy organic carbon, in any carbon reservoir. This measure eliminates the incentive for carbon consumers to avoid carbon fees through temporal shifts in carbon emissions, and can be used to measure cross-border movement of embodied carbon, thus eliminating the incentive for carbon consumers to avoid carbon fees through spatial shifts in carbon emissions.

We view our proposed carbon metric as possibly the first element in what will become a multi-dimensional carbon metric vector and, by extension, of climate change potential (as measured by metrics such as ecosystem services) that will be needed to account for the myriad of factors that affect climate change.

For maximum economic effectiveness, any carbon fee based on anthropogenic changes in carbon quality must be assessed on the actor involved at the same time and place as the pertinent activity. Any delay or displacement of any carbon fee will only contribute to a reduced intensity of the price signal that is intended to influence the actor's behavior.

Such immediate placement of carbon fees based on changes in carbon quality will ensure the capture of the broadest, most comprehensive, and equitable measure of the changes in climate potential due to anthropogenic activity. Economists have long argued that capturing the effect of upstream activity is important to implement an efficient and effective carbon management strategy.

Benefits

The most pronounced benefit of having such a carbon metric is the ability to now account for the climate change potential in everyday commerce, including domestic and international trade, all financial transactions, all investment decisions, and consumer activity for any and all changes in carbon quality. The carbon metric can be used to rank all entities and institutions, ranging from individuals and companies to multinational corporations and entire nations.

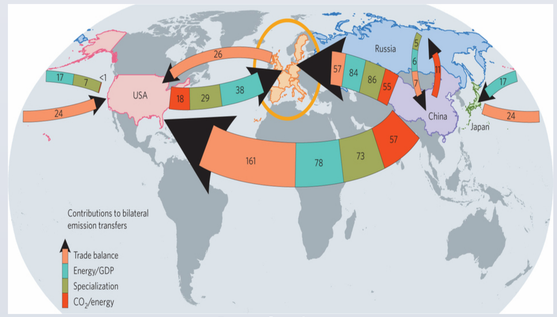
With proper placement of appropriate carbon fees based on changes in carbon quality, such upstream fees will follow the embodied carbon throughout the production cycle, allowing for the greatest economic efficiency.

By properly accounting for the climate change potential in international trade, the carbon metric will permit the use of existing accounting systems to implement a worldwide system whereby individual countries choose a carbon management strategy that is best suited to their factors of production, balanced by carbon fees on imports and credits on exports that reflect domestic policies on carbon management.

Metric-based carbon fees and credits would stimulate and nurture longer-term investment in research and development as well as capital for the production of lower-carbon goods and services. Such an approach would allow those countries that wish to pursue a more aggressive carbon management to do so at a lower risk from industries in higher carbon-intensive economies. The lower risk would allow nascent low-carbon industries to reach the economies of scale often necessary to compete on an economic level now occupied by higher carbon-intensive industries and economies.

Another advantage of the carbon metrics themselves is that they allow for two degrees of freedom which are missing from the current worldwide negotiations to reduce carbon intensity. First, the carbon metrics can be developed independently by the scientific community separate from the political posture of individual carbon-intensive entities that wish to maintain their market share in energy and feedstocks. Second, the carbon metrics allow for countries to pursue low-carbon strategies without a complete worldwide agreement to lower carbon intensity.

Implementing such flexibility would allow early adopter countries to pursue a greater reduction of carbon intensity than would be called for in any one-size-fits-all approach to mitigate climate change, while providing trade incentives via carbon parity adjustments for those countries that would not otherwise pursue such a reduction strategy.



Conclusions

Given the importance of carbon to those countries with high carbon avidity, our view is that efforts to lower carbon intensity via any Cap-and-Trade scheme will prove unworkable and unenforceable worldwide. Combined with the dilution effect from both spatial and temporal leakage of carbon emissions, attempts to reach a statutory worldwide agreement that does not provide for the varying factors of production among countries to reduce carbon intensity will likely be fruitless.

Contact

Email: F. DeGroff at fdegroff@mail.ccsf.edu

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