Embodied Carbon in Traded Goods

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Abbreviations and Acronyms

BEET	balance of emissions embodied in trade
CO_2	carbon dioxide
GDP	gross domestic product
GHG	greenhouse gas
ISO	International Organization for Standardization
LCA	life-cycle assessment
MFN	most favoured nation
OECD	Organisation for Economic Co-operation and Development
TERI	The Energy and Resources Institute
U.S.	United States

Summary of key issues, challenges:

- The term "embodied carbon" refers to carbon dioxide emitted at all stages of a good's manufacturing process, from the mining of raw materials through the distribution process, to the final product provided to the consumer. Depending on the calculation, the term can also be used to include other GHGs.
- Important questions in climate change and international trade discussions are linked to embodied carbon. Should emissions be allocated at the point of consumption (meaning a calculation like embodied carbon), or at the point of manufacture (meaning a calculation like those currently performed for the purposes of the Kyoto Protocol)? Should international trade be considered in a future climate change agreement to avoid "carbon leakage" to developing countries?
- These questions have particular implications for a country like China that has experienced phenomenal economic growth, matched by increases in energy use, aggregate GHG emissions and exports. While embodied carbon may be a negotiating issue for China and other rapidly growing developing nations that are under pressure to curb increases in energy use and GHG emissions, there is still a lack of good research results to fully support the discussion.
- Initial research indicates that, in general, Annex B countries are net importers of CO_2 emissions, but there is considerable variation. And the various assessment techniques used to calculate embodied carbon—e.g., life-cycle assessment, ecological footprint, hybrid LCA—face several challenges, including methodology, definition of boundary, data availability and cost.
- The concept of embodied carbon also is important in the discussion of competiveness issues, whereby those countries implementing emissions reduction policies will have to compete with exports from countries without mandatory emission reductions, where costs of production may be lower as a result. The basis for trade measures (e.g., border carbon adjustment) to level the playing field could be embodied carbon in products.
- But, is the concept of embodied carbon compatible with the principles of the multilateral system of trade? Specifically, can discrimination based on embodied carbon be accommodated in existing trade law? Given the proliferating number of schemes, both private and governmental, this question is important.

Summary of ways forward:

- While there is some discussion of accounting for a nation's emissions consumption in a new international climate agreement, more research is needed to assist the international community in properly assessing policy options.
- Embodied carbon calculations have only been undertaken for a limited number of products and a wider coverage of products is needed. Related to this is the need for a more systematic analysis of embodied carbon to ensure consistency across calculations.
- Regional analysis is also needed, especially in developing countries where the same products could have very different levels of embodied carbon. And international comparative analysis is essential to understand mitigation potential and links with trade issues.
- It is important to begin to examine known trade case law to attempt to determine if embodied carbon is compatible with the principles of the multilateral system of trade.

The concept of embodied carbon

The term "embodied carbon" refers to carbon dioxide emitted at all stages of a good's manufacturing process, from the mining of raw materials through the distribution process, to the final product provided to the consumer.[1] Depending on the calculation, the term can also be used to include other GHGs as well.

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The discussion of the importance of CO_2 embodied in global trade has been going on for over a decade (see for example, Shui and Harriss, 2006). Wyckoff and Roop's (1994) evaluation of the carbon embodied in the imports of manufactured goods in the six largest OECD countries between 1984 and 1986 warned that many national GHG policies, which are predicated on controlling emissions by reducing domestic GHG emissions, might not be effective if imports contribute significantly to domestic consumption. Schaeffer and de Sá (1996) studied the carbon embodied in Brazilian imports and exports from 1970 to 1992, and expressed concerns that developed countries were transferring CO_2 emissions to developing countries through offshore manufacturing and production of goods. Munksgaard and Pedersen (2001) questioned whether the producer or the consumer of goods should be responsible for CO_2 emissions; and Jiun-Jiun Ferng (2003) suggested using a benefit principle to assign responsibility for pollutant emissions related to the consumption of goods.

This paper explores the embodied carbon concept and its possible impact on trade policy and the climate negotiations. It first provides context by examining how embodied carbon is measured and the challenges related to measurement. The paper then looks at implications for the climate change and trade regimes.

Calculating embodied carbon

A number of tools and methodologies have been developed to calculate embodied carbon. Key assessment techniques—e.g., life-cycle analysis, carbon footprint, hybrid life-cycle analysis. These are discussed below, along with the challenges they face.

Assessment techniques

Life-cycle assessment is a production-based analytical tool that can used to undertake embodied carbon analysis. It includes the systematic evaluation of the environmental aspects of a product or service system through all stages of it life-cycle—extraction and processing; manufacture; transport and distribution; use, re-use and maintenance; recycling and final disposal.

Applied to embodied carbon, LCA would apply only to specific stages of the full life-cycle, not covering emissions generated during the use and final disposal stages. And it would be limited to an assessment of carbon or GHG emissions, ignoring other aspects of environmental damage. The Carbon Trust (2006) developed a carbon LCA methodology to assess the carbon footprint of different products by analyzing the carbon emissions generated by energy use across the supply chain.

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1 Han *et al.* (2008) refer to this as Mining to Products. The concept is also referred to as source to store, cradle to grave, or cradle to market, depending on the calculations. Embodied carbon is also sometimes referred to as embedded carbon or virtual carbon.

Ecological footprint analysis is another consumption based tool. Wackernagel and Rees (1996) defined the ecological footprint as the area of productive land and water systems required to produce the resources that the population consumes and assimilate the wastes that the population produces. The ecological footprint tool is used to analyze: i) the amount of resources we have compared with how much we use; ii) the amount a particular population group is dependent upon resource imports from outside its habitation area; iii) the amount this group depends on outside areas for the waste assimilation; and iv) whether nature's productivity is adequate to meet the future requirements of that particular population group. The ecological footprint is measured in "global hectares," an area unit adjusted to average world bioproductivity, and it can be applied for a product, community or region.

TERI (2008) developed the *Hybrid Life-Cycle-Analysis*, which can be used for the assessment of micro-systems such as individual products (e.g., recycled paper). This methodology combines a bottom-up process analysis with a top-down environmental input-output approach. In this approach, the process analysis includes the collection of on-site, first and second-order process data on embodied carbon or carbon footprints for the product or service; while higher-order requirements are covered by input-output analysis.

Challenges

The calculation of embodied carbon faces several challenges, including choice of methodology, definition of boundary and data availability.

Embodied carbon can be calculated by either top-down and bottom-up methods. Top-down methods using input-output analysis have often been applied to estimate embodied energy, CO_2 emissions, pollutants and land appropriation from international trade activities (Wyckoff and Roop, 1994; Schaeffer and de Sá, 1996; Machado *et al.*, 2001; Munksgaard and Pedersen, 2001; Muradian *et al.*, 2002; Ferng, 2003; Hubacek and Giljum, 2003; Shui and Harriss, 2006). This methodology can be used to analyze a country's embodied carbon in imports and exports as a whole; but it has difficulties at the sectoral level. Input-output tables are expressed in value added by sector, and each sector spans a number of different specific products, each of which will have different carbon-to-value-added ratios, or *carbon co-efficients*. Since the sectoral carbon co-efficients are estimated averages of those ratios for all the products in each sector, they are not particularly useful for calculating the embodied carbon attributable to a given product. Of course there are also major uncertainties involved in estimating these co-efficients in the first place.

The bottom-up method calculates embodied carbon by examining the production processes of specific products. A large amount of preliminary data is needed; the calculation of embodied carbon for one product requires data for the many inputs to the manufacturing process. A single computer, for example, is an assembly of hundreds of different components, all potentially sourced from different producers, perhaps in different countries, all produced in different manners, using energy from various different sources, all with their own carbon coefficients. The level of detailed data and technological information required may not be available in all developing countries, because of weak data collection and statistics agencies. The TERI Hybrid Life-Cycle-Analysis, described above, attempts to get around the challenge of methodology choice by combining top-down and bottom-up analysis in one methodology.

Boundary issues, such as the range of emissions, are also a challenge in the calculation of embodied carbon. Full LCA of GHG emissions for a particular product could, in principle, include an examination of emissions associated not just with inputs to the product, but also the inputs to those inputs, and so on up the product's value chain. Many methodologies limit the calculation of embodied carbon to major inputs, and an often seen assumption is omitting the calculation of embodied carbon for equipment used for the manufacturing process. Established methodologies provide guidance on boundary issues, and include the

GHG Protocol developed by World Resources Institute and the World Business Council for Sustainable Development, and the ISO 14060 series that provides guidance for assessment of GHGs.

Other challenges are the cost and time requirements for analysis of embodied emissions, which can be prohibitive. Data collection and availability has been improved through work at the sector level.

The complexity of measuring embodied carbon is illustrated in the Blanke's (2006) life-cycle analysis of apples, which compares the primary energy consumed for both imported and home grown apples in the Rhein-Ruhr area in Germany in the month of April. The primary energy to produce home-grown apples included energy for five months of cold storage, compared to the energy requirements of transporting apples from New Zealand (28 days transport) or South Africa (14 days transport). The increased energy required to import fresh fruit from overseas was partially offset by the energy needed for cold storage of domestic apples. But in order to *fully* offset the differences in embodied carbon for fruit imports from South Africa or New Zealand, home-grown apples had to be stored locally for nine or 18 months, respectively, i.e., in the latter case beyond the next harvest. As such, in this case, the embodied carbon differential between local and imported goods changed with the month of the year, and the age of the local produce.

Implications for the international climate change regime

The calculation of embodied carbon can be undertaken for a variety of reasons related to the climate change regime, including generating officially recognized GHG reduction "credits" for use in meeting mandatory emission targets, obtaining recognition for GHG reductions under voluntary programs, and offsetting GHG emissions to meet internal company targets for public recognition or other internal strategies.

Domestic policies for emissions reductions can be guided by embodied carbon calculation. An example is carbon labelling policies that show consumers the carbon content of a product, allowing consumers to select low-carbon products, cut emissions by purchasing choices and pressure suppliers to opt for low-carbon options in processes and supplies. Proposed legislation in the California State Assembly, "The Carbon Labeling Act of 2008," would create a voluntary program for carbon labels on consumer products, much like nutrition labels on food items. The legislation could help California in its effort to meet the 25 per cent reduction of GHG emissions by 2020 mandated by the Global Warming Solutions Act. California envisions a cradle-to-market methodology that relies on available industry-wide secondary data for many inputs to the production process, and company-specific primary data for the California-based portions of the manufacturing process. The approach would consider raw material acquisition, transportation to the factory, manufacturing and transportation to market.

There is also some discussion of accounting for a nation's emissions consumption in a new international climate agreement. This would be a departure from the Kyoto Protocol that looks at emissions on a country-by-country basis and uses production-based (point of emissions) accounting methods to calculate a country's GHG emissions. This includes looking at domestic activities such as energy use, mining, industrial process, land use and sinks. In contrast, consumption-based accounting looks at the carbon embodied in goods in the country of where the good is consumed.

This has particular implications for a country like China that has experienced phenomenal economic growth, matched by increases in energy use and aggregate GHG emissions. China has also experienced a remarkable increase in exports. Peters and Hertwich (2008) assessed the balance of emissions embodied in trade in trade (BEET) for a number of countries, and concluded found that China's BEET (embodied emissions in exports less embodied emissions in imports) was 585.5 $MtCO_2$, compared to the United States'

BEET of -438.9 $MtCO_2$ (see Table 1). In general, Annex B countries—those with Kyoto targets—were found to be net importers of CO_2 emissions. But as a percentage of production-based emissions (i.e., the higher the figure, the more impact from production-based activities would have on the country's nation mitigation target), there was considerable variation. The highest impacts were for small-trade intensive economies.

Table 1: Balance of Emissions Embodied in Trade (BEET) for select countries

Annex B			Non-Annex B		
	BEET $MtCO_2$	BEET as a % of production-based emissions		BEET $MtCO_2$	BEET as a % of production-based emissions
Switzerland	-63.1	-122.9%	Singapore	-62.8	-128.2%
Latvia	-4.6	-60.7%	South Korea	-45.4	-11.4%
United Kingdom	-102.7	-16.6%	Morocco	-2.5	-6.3%
Germany	-139.9	-15.7%	Mexico	-17.6	-4.5%
Japan	-197.0	-15.3%	Brazil	+2.5	+0.8%
United States	-438.9	-7.3%	India	+70.9	+6.9%
Canada	15.5	+2.8%	China	+585.5	+17.8%
Australia	57.9	+16.5%	Indonesia	+58.1	+19.0%
Russia	324.8	+21.6%	South Africa	+123.5	+38.2%

Source: Peters and Hertwich (2008).

While this may be a negotiating issue for rapidly growing developing nations that are under pressure to curb increases in energy use and GHG emissions, there is still a lack of good research results to fully support the discussion.

Implications for the trade regime

Under the Kyoto Protocol, Annex I countries agreed to reduce emissions by a collective average of five per cent below their 1990 levels. These countries have adopted domestic mitigation policies and programs to help meet their reduction targets, including energy efficiency standards, emissions trading schemes and carbon taxes.

These mitigation measures normally increase the cost of industrial products, at least in the short run. This raises competiveness issues, whereby those countries implementing emissions reduction policies will have to compete with exports from countries without mandatory emission reductions, where costs of production may be lower as a result. Industry representatives, and some politicians, have reacted to these concerns by calling for the introduction of measures, including trade measures, to offset competiveness imbalances and level the playing field.[2] The basis for levying the taxes could be embodied carbon in products.

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2 For a more in depth discussion of these measures see the companion paper in this series: *Border Carbon Adjustment*.

Examples of such proposals have come from various levels of government in the European Union and the United States. In the United States, the Leiberman-Warner bill (*America's Climate Security Act*) now before Congress includes a provision aimed at encouraging other nations to start reducing the GHG emissions.[3] If, two years after the enactment of the U.S. program, it is determined that a major emitting nations has not taken comparable action, the legislation would require importers of GHG-intensive manufactured products from that nation to purchase U.S. offsets. The number of offsets to be purchased would be calculated based on the embodied carbon in the good in question. Such a regime would be a simple extension of the concept of consumer-based accounting for carbon emissions. If the responsibility for those emissions lies with the consumer, then it can be argued that final responsibility for regulating those emissions should lie with the consumer government as well.

Another extension of this principle can be seen in the concept of "food miles"—the embodied carbon in a traded good as a result of its transport. The reasoning behind this concept is that the further a good travels, the more it contributes to climate change (though some analysts acknowledge that the mode of transport matters). The partial nature of this approach, however, has been called into question by studies arguing that on a life-cycle basis embodied carbon can actually be *lower* in goods imported even from very distant countries than it is in locally produced goods (Williams, 2007; Saunders *et al.*, 2006). What seems to matter more is how the goods were produced, transport being only one of a long chain of activities necessary to bring a good to the consumer.

Is the concept of embodied carbon compatible with the principles of the multilateral system of trade? Specifically, can discrimination based on embodied carbon be accommodated in existing trade law? Given the proliferating number of schemes, both private and governmental, this question is important.

The key principle of trade law is non-discrimination: goods from foreign producers must get no worse treatment than like goods from domestic producers (national treatment), and goods from one foreign country must get no worse treatment than like goods from any other foreign country (MFN treatment). With respect to discrimination on the basis of embodied carbon, the million-dollar question is how to define "like" goods. Is a tonne of inefficiently produced steel "like" a tonne of efficiently produced steel? If so, then tariffs based on embodied carbon may violate the principle of non-discrimination.

This question is far from simple, and is examined in greater depth in the companion paper to this one, on border carbon adjustment. In the end, it is impossible to say in the abstract whether trade measures based on embodied carbon are legal or illegal from a trade law standpoint; any such judgement will depend on the nature of the specific measure. And the only definitive answer in any case would come from a dispute panel. But it is possible to say that trade law is an important consideration for such schemes, and that they should be vetted as best they can in advance against known trade case law.

Concluding thoughts

There are gaps in our understanding of embodied emissions from a climate change and trade perspective, and more research is needed to assist the international community in properly assessing policy options. One area requiring further work is to increase the number of products analyzed. Embodied carbon calculations have only been undertaken for a limited number of products and a wider coverage of products is needed. Related to this is the need to extend boundary limitations to allow a more systematic analysis of embodied carbon calculations. More detailed process analysis is necessary in LCAs, including an assessment of the full range of manufacturing inputs in the supply chain.

3 Bill S-3036. This bill replaced Lieberman-Warner's S-2191. Among other things, the bill has been amended such that the trade provisions become effective after two years, rather than eight. There is a variety of similar bills either before Congress or in the works.

Regional analysis is also needed, especially in developing countries where the same products could have very different levels of embodied carbon. And international comparative analysis is essential to understand mitigation potential and links with trade issues.

Finally, more attention needs to be paid to embodied carbon and its possible impacts on the climate change regime and negotiation process. While this would be a very political analysis, research is needed to extend the debate beyond rhetoric and perceptions of negative impact on competiveness that are not backed up with solid data. As noted earlier, it is important to begin to examine if embodied carbon can be accommodated in existing trade law, and if the concept is compatible with the principles of the multilateral system of trade.

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