U.S. Community Protocol
for Accounting and Reporting of Greenhouse Gas Emissions

Appendix H: Emissions Associated with the Community's Use of Materials and Services: *Accounting for Trans-boundary Community-Wide Supply-Chains*

Version 1.1

July 2013

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Introduction

This appendix provides methods for quantifying the greenhouse gas (GHG) emissions from trans-boundary sources associated with other materials and services used by the whole community. Energy use and GHGs from the community's built environment, transport, solid waste, wastewater, and agricultural activities are detailed in other accounting appendices. To provide an expanded perspective, this appendix details methods to incorporate trans-boundary GHG emission sources associated with supply-chains providing *other* materials and services used by the whole community, that are not already accounted for in other accounting appendices of this protocol.

Trans-boundary GHG emissions can be organized into the following three categories:

- Key community-wide supply chains: Life cycle GHGs from producing the supply chains of fuel, food, cement and other materials used by the community as a whole, i.e., by a community's homes, businesses and industries considered together. Methods to account for emissions from some of these community-wide supply chains are detailed in this appendix. Supply-chain emissions for electricity and fuels used in community built environment and transportation sectors are addressed in Appendix C: Built Environment Emission Activities and Sources (see accounting method BE.5) and Appendix D: Transportation and Other Mobile Emission Activities and Sources (see accounting method TR.9), respectively.
- Household and Government supply-chains: Life cycle GHG emissions associated with the use of goods and services by economic final consumption (households, and government). The accounting method for these emissions has significant overlap with the method used for community-wide supply chains, but while supply chain emissions are typically calculated for one material at a time, integrated economic or other models can estimate emissions for the entire basket of all materials and services consumed. These consumption-based emissions are detailed further in Appendix I – Consumption-Based Emissions of this Protocol.
- Individual industry supply-chains: Life cycle GHG emissions associated with supply chains, e.g., materials and services, used by local industries – e.g., education, healthcare, manufacturing, hospitality, or other dominant industry in the community. This Protocol does not provide accounting guidance for these types of emissions, but it is important to acknowledge them nonetheless.

Accounting of "key community-wide supply chains" (this appendix) and "household and government supply chains" (also called Consumption-Based Emissions; Appendix I) will be a new activity for many climate professionals. It is important to understand key differences between these two approaches. The following table highlights a few of the major differences.

Table SC.1 Major Differences Between Key Trans-boundary Community-wide Supply Chains and Household and Government Supply-Chains

	Trans-boundary Community-Wide Supply-Chains	**Household and Government Supply-Chains (Consumption-Based Accounting)**
Community members covered	All users of materials and services in a community, e.g., households, government, businesses, and industries.	Households and government[1]
Commodities covered	Typically the evaluation is performed on an individual commodity basis. Food and cement are two common examples.	Typically performed (using macroeconomic models) for the entire basket of consumption, e.g., all materials and services (including electricity and fuels) consumed. Local energy use (electricity, natural gas, fuels) by households and government are already accounted for in previous sections of this protocol.

Reporting

GHGs from the key community-wide supply-chains can be included in an inventory as an optional reporting framework as described in sections 2.3.1 and 4.3 of the Protocol.

Overarching Method

In principle, methods for computing GHG emissions from all the above trans-boundary categories are similar.

Data Needs

Two data items are generally required:

1. Annual flow of material or services (M) used by the community – e.g., the whole community, households, industries or government, as the case may be. Material flows are sometimes represented in units of mass or volume of each material per year, e.g.,

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[1] Household and government supply-chains are sometimes supplemented with estimates of business capital/inventory formation. See Appendix I: Consumption-Based Emission Activities and Sources for details.

tons of cement, although they can also be expressed in units of dollars ($), e.g., $ spent on food. Service flows are typically represented in $ units, e.g., $ spent on education or food.

2. <u>Life cycle GHG emissions factor (EF) for producing these goods or provisioning these services.</u>

The annual material or service flows (M) are multiplied by the life cycle GHG emissions factor (EF) to compute annual GHGs associated with the supply chains of each material/service.

Equation SC.1

GHG Emissions (CO_2e) = Material or Service Flow (M) X *Emission Factor (EF)*

<u>UNITS</u>: Care should be taken that units match up. For instance, if annual material flow is in tons of cement used, the EF should be tons of CO_2e per ton of cement produced and computed from nationally recognized LCA databases such as the NREL's LCI (NREL, 2012). If materials and services are expressed in $ of economic activity, the EF should likewise be tons of CO_2e per $(USD) and is computed from economic input-output life cycle models, such as Carnegie Mellon University's Economic Input-Output Life-Cycle Assessment (EIOLCA) model, www.eio-lca.net. Such economic models typically report emissions factors for a given year (the currently publicly-available model is for 2002), and so economic activity in other years must be scaled appropriately.

EFs obtained from models such as EIOLCA can be reported either in producer or purchaser prices. "Purchaser prices" refer to what the purchaser pays, while "producer prices" refers to what the producer receives. For example, a mango may have a purchaser price of $1.00 (what the shopper pays for the mango at the store), but the "producer price" (what the producer receives) is only $0.55 (the other $0.45 going to pay for transport, wholesale, and retail margins). Economic activity is often reported in purchaser prices (for the Consumer Expenditure Survey) but sometimes is reported in producer prices (for some other sources of purchasing data, such as the IMPLAN economic model; in the example above, a household's $1.00 expenditure on mango might be reported in producer prices as 4 separate expenditures: a $0.55 expenditure [in producer prices] on mangos, a $0.15 expenditure [in producer prices] on retail services, and so on.). Emissions factors based in producer prices account for production, wholesale, retail and transport separately, while emissions factors based in purchaser prices have wholesale, retail, and transport emissions embedded in them. While data from the Consumer Expenditure Survey (CES) is readily available, its use of purchaser prices requires the use of emissions factors denominated in purchaser prices, which creates a potential for double-counting; for example, using CES data for food purchases (and emissions factors expressed in purchaser prices) will result in estimates of the emissions for food production (typically trans-boundary) as well as freight, wholesale and retail operations, with the emissions from retail operations already accounted for in the Built Environment Appendix C (if the retail location is in the community).

In any case, it is important to confirm that the correct price model is used; if expenditures are estimated in purchaser prices, then a purchaser price-based emissions factor should be used. For example, as food expenditures by homes obtained from the CES are in purchaser prices, the comparable food EF should be built from the EIOLCA purchase price model, with potential double counting noted (e.g., Built Environment for emissions from energy used at restaurants).

The following examples show how equation SC.1 can be applied to compute the trans-boundary and life cycle GHG associated with producing several categories of materials and supply chains.

Key community-wide supply-chains

Value-Added relative to Basic Emissions Generating Activities

Direct energy use by the whole community as well as provision of water, and waste management is already covered in the Protocol's Basic Emissions Generating Activities (section 2.2), but life cycle GHG emissions for energy, as well as emissions associated with other materials and services used by the whole community are not. In addition to upstream impacts of electricity and fuels, several studies have identified a variety of materials and services to be important in various communities, including but not limited to: food, cement, other materials used in construction (as well as construction services), vehicles and parts, electronics, clothing, other manufactured goods, and other services providing air travel, and freight (e.g., Ngo & Pataki, 2008; Ramaswami et al., 2008; Kennedy et al., 2009; Hillman & Ramaswami, 2010; Baynes et al., 2011; Chavez et al., 2012; Stanton et al., 2011[2]).

Methods to estimate Material Flow (M) and Life Cycle Emission Factors (EF)

An annual urban material flow (M) for the amount of the material used by the community (i.e., gasoline, diesel, jet fuel, food, cement, iron, steel, etc.) is estimated for the accounting year. Materials use for these items can be obtained in different ways from different data sources. Following are typical methods for obtaining M and EF, and for computing GHG for each of the trans-boundary materials/services discussed here. We present methods for computing M, show typical EF, and then show a sample calculation.

Please note that supply-chain emissions for transportation fuels, electricity, and other fuels used directly in communities (e.g., natural gas in boilers) are addressed in Appendix C: Built Environment and Appendix D: Transportation and Other Mobile Emission Activities and Sources.

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[2] Stanton et al's work includes consumption-based emissions inventories for Oregon, King County, and San Francisco. While not full community-wide supply chain inventories, they are mentioned here because if commodities are identified as contributing significantly to emissions as a result of community consumption (limited to household, government, and business capital/inventory formation), the emissions from community-wide expenditures (including business operations) can be expected to be even higher.

SC.1 Food

The intent in this section is to compute supply chain agricultural and livestock GHG from producing the food used in communities since much of this production occurs outside the community boundary. If significant farming and livestock production occurs within the community, those GHGs must be subtracted from the supply chain GHGs computed here to avoid double counting since food use intends to focus on agricultural and livestock emissions.

SC.1.1 Food Use (M)

- Community-wide flows of food include food used by homes (at home and outside of home in local restaurants), plus food used by businesses/hospitality industries that may serve visitors, e.g., local restaurants serving visitors.
- Food at home: Consumer Expenditure Surveys (CES) (BLS, 2011) has traditionally been the source for estimating dollar expenditures on food consumed within the homes. http://www.bls.gov/cex/
  - Examples of annual Food at Home Expenditure from US cities (in 2002$) (BLS, 2011), shows that food expenditures by households does not vary much across US cities:
    - San Francisco = $3,567; Denver = $3,463; Miami = $3,296; NYC = $3,388
  - National food expenditure benchmark: Average US food expenditures for food at home is $3,120 /HH/yr (in 2002$).
    - Note, if using EIOLCA, expenditures must be converted from current year $ to 2002$, as the EIOLCA is built from the 2002$ US economy.
    - For this conversion one can use the BLS price inflation tool (http://www.bls.gov/data/inflation_calculator.htm)

- Food in Local Restaurants: Food purchases by residents outside of the home in local restaurants, and by visitors in local restaurants may be estimated through restaurant tax receipts and likewise from other food vendors. This approach has been adopted by Eagle County, Colorado (Eagle, 2005), which estimated direct purchases of food (only) from sales tax revenues. Utility-related impacts (at the restaurant) are already accounted for elsewhere in this Protocol. If, however, the food-only component of restaurant sales is not known, then an alternative approach is needed. The preferred option is to use total restaurant sales (revenues), and to adjust them to account for the food-only component. To isolate just the upstream impacts of food served at restaurants, take total restaurant receipts and multiply by 0.25, a rough approximation of the percentage of restaurant receipts that go to pay for food (25%). Multiply this result by an emissions factor for food. Other restaurant expenditures, such as for employee labor, natural gas, electricity, water, and supplies are accounted for in other sections of this Protocol, or not at all.

- Total Community wide food flows are computed in $ units as the sum of the above two; food used at home and food used at local restaurants/hospitality industry.
    - Note food flows to industries are not necessary to compute since the energy use in local bakeries, breweries, etc. is already addressed in the Built Environment Appendix C. If such products are used (eaten) within the community, their upstream agricultural supply chain GHGs will count in food use at home or in local restaurants.

SC.1.2 Food Emissions Factor

- The life cycle EF for food is obtained from EIOLCA. The EF for food is estimated as 1.6 kg-CO_2e/2002$ for a typical US household diet. The following table shows some of the typical EF for food commonly reported by CES.

Table SC.1.1. Food EFs for various food categories (in purchaser prices)

Food Category	**EIOLCA GHG EF (kg-CO_2e/2002$)**
Food at home	
Cereals and bakery products	0.85
Meats, poultry, fish, and eggs	1.86
Dairy products	2.39
Fruits and vegetables	0.89
Other food at home	0.98

From: Hillman, T. (2008). Doctoral Dissertation.

SC.1.3 Sample Calculation

- The annual expenditures for food at home for a community of 4,000 households is reported as $3,200 /HH in 2002$. The local government uses restaurant sales tax data to determine that total expenditures at restaurants by residents and visitors equated to $10 million in 2002$. The life cycle GHGs for food consumed by the whole community is computed as follows:

  Life Cycle GHGs from food consumption at home = ($3,200 /HH/yr)(4,000 HH)(1.6 kg-CO_2e/2002$)(1 mt/1,000 kg) = **20,480 mt-CO_2e**

  Life Cycle GHGs from food consumption at restaurants = ($10,000,000/yr)(0.25)(1.6 kg-CO_2e/2002$)(1 mt/1,000 kg) = **4,000 mt-CO_2e.**

  Life Cycle GHGs from total food consumption = (20,480 mt-CO_2e) + (4,000 mt-CO_2e) = **24,480 mt-CO_2e**

SC.2 Cement

SC.2.1 Cement Material Use

- The Portland Cement Association (PCA) reports on county level cement use in their *Apparent Use of Portland Cement and Ready-Mix Concrete* report. The report is available annually for a cost of $500, and details use by major users (i.e., residential, motels/hotels, public buildings, highways, etc.)
- The US Economic Census (Census, 2004) is used to approximate GHG emissions from cement production used in cities. This method has been used in various studies (e.g., Ramaswami et al, 2008; Hillman and Ramaswami, 2010), and assumes the production of ready-mix concrete (NAICS 32732) as a proxy for cement use in the community. Because concrete in ready mix trucks sets within 30 minutes, the ready-mix concrete operations are assumed to be close to points of use, and hence represent community wide use of concrete (a % of which is cement: 0.1446 mt cement/mt of concrete)
- Ready-mix concrete expenditures in $ are converted to metric tons of cement using a factor of 0.002 mt-cement/$ (ready-mix), which is derived from total US cement use (PCA, 2005) divided by total US expenditures of NAICS 32732 (Census, 2004).

SC.2.2 Cement Emissions Factor

- The life cycle EF from cement production is obtained from the National Renewable Energy Laboratory's (NREL) LCA database. The EF for cement production is estimated as 1 mt-CO_2e/mt-cement.

SC.2.3 Sample Calculation

- The annual cement expenditures (or use) for a community of 10,000 people are reported as $250 cement expenditures/capita. The life cycle GHGs for cement use is computed as follows:

  Life Cycle GHGs from cement use = ($250 cement expenditures/capita)(0.002 mt-cement/$)(10,000 people)(1 mt-$CO_2$e/mt-cement) = **5,000 mt-CO_2e**.

SC.3 Other Materials

With the appropriate data, local governments can also estimate the supply-chain GHGs associated with other materials used in cities.

SC.3.1 Waste Generation as a Proxy for Materials Use

One source of data for material flows (M) comes from waste data. For certain materials, waste data offers a useful proxy for materials use by the community. This is especially true for materials that are not consumed (not food) and that have relatively short service lives (e.g., newspapers and packaging). Waste data can also serve as a proxy for material use for longer-lived materials, such as carpet and lumber, although the time lag between production (supply chain emissions) and disposal should be acknowledged.

It is important to understand the difference between “waste disposal” and “waste generation”. “Waste disposal” refers to materials that are disposed of in landfills and incinerators. “Waste generation” includes all discards, both those that are disposed of, as well as those that are recovered such as through recycling. Waste disposal data (by material type) is readily available for most communities; waste composition studies can be used to disaggregate disposed tons into material types such as ferrous metal, carpet, newsprint, etc. Please see Appendix E: Solid Waste Emission Activities and Sources, Table SW.2, for more details on this approach.

Estimating waste generation is more difficult, as it requires knowing both tons disposed (by material type) and tons recovered (by material type). While data for waste disposal (by material type) for community-generated waste is typically relatively easy to attain, many communities will not have ready access to estimates of community-generated waste recycled by material type. However, some communities will find such data through their city, county, or state recycling office. If recovery data is available, it can be added to disposal data to produce estimates of waste generation (again, by material type). If waste recovery data is not available, a community can estimate by pro-rating from comparable communities where data is available, or use national averages (available from the U.S. EPA). Waste generation is estimated by adding disposal tonnages with recovery tonnages.

Waste generation is a better proxy of material use than waste disposal, and should be used if possible. If waste generation cannot be estimated, waste disposal data (again, by material type) will provide a partial (though less complete) proxy of material flows, and disposal data can be used with limitations clearly noted in the inventory report. It should be noted that while recycling serves to mitigate some of the upstream emissions from raw material extraction and manufacturing, even materials that are recycled contribute to greenhouse gas emissions; materials that are subsequently recycled should not be excluded from estimating supply chain emissions unless data is not available.

SC.3.2 Supply-Chain Emissions Factors for Various Materials

Table SC.3.1 provides emissions factors (in mt-CO2e/short ton) for the raw material acquisition and manufacturing of various materials. The "current mix of inputs" refers to national averages for mixtures of recycled and non-recycled content.

Emissions associated with disposal are accounted for separately, in Appendix E: Solid Waste Emission Activities and Sources.

Communities may choose to use emissions factors from other information sources, and for materials (including products) not included in Table 2. Documentation of sources should be provided in the inventory report.

Table SC.3.1. Upstream Emissions Factors in mt-CO_2e/short ton

Material X	**Raw Material Acquisition and Manufacturing for Current Mix of Inputs mt-CO_2e/short ton**
Asphalt Concrete	0.11
Asphalt Shingles	0.2
Carpet	4.02
Clay Bricks	0.29
Concrete	NA[1]
Drywall	0.22
Fiberglass Insulation	0.39
Fly Ash	NA[1]
Glass	0.53
Metals	
Aluminum Cans	8.26
Steel Cans	3.19
Copper Wire	7.38

Table SC.3.1. Upstream Emissions Factors in mt-CO_2e/short ton (continued)

Material X	Raw Material Acquisition and Manufacturing for Current Mix of Inputs mt-CO_2e/short ton
Organics	NA[1]
Paper Products	
Corrugated containers	0.88
Magazines/Third Class Mail	1.69
Newspaper	1.94
Office paper	1.04
Phone Book	2.46
Textbook	2.17
Mixed paper (general)	1.19[2]
Mixed paper (primarily residential)	1.19[2]
Mixed paper (primarily office)	3.16[2]
Personal Computers	55.78
Plastics	
HDPE	1.77
LDPE	2.25
PET	2.07
Tires	4.34
Vinyl Flooring	0.63
Wood Flooring	0.41
Wood Products	
Dimensional Lumber	0.18
MDF	0.39

1. Not Applicable--these materials are not modeled by WARM for upstream emissions
2. WARM does not have data on the current mix of inputs for these factors. This factor is based on WARM's emission factor for 100% Virgin Inputs

Source: US EPA WARM tool (version #11)

SC.3.3 Sample Calculation

- A community’s recycling office estimates that the community collects for recycling 500 tons/year of telephone directories.
- Relevant waste composition studies, applied to the community’s annual disposal of solid waste, are used to estimate that an additional 700 tons/year of telephone directories are disposed of.
- Total “waste generation” of telephone directories is thus 1,200 tons/year.
- This is assumed to be a reasonable proxy for the use of telephone directories by the community. The life cycle GHGs from production of telephone directories for use by this community are computed as follows:

Supply-chain GHGs from telephone directories = (1,200 short tons/year)(2.46 mt-CO_2e/short ton) = **2,952 mt-CO_2e**.

SC.3.4 Materials not Included

Additional community wide supply chains may also be important and further studies of large numbers of cities can help identify any other key supply chains that serve all cities.

SC.4 Long-Distance Freight

Some communities are interested in estimating the emissions associated with long-haul of goods that are used by the community. This section provides a methodology for roughly estimating these emissions, but some important caveats must be noted first.

First, the potential exists for some double counting of emissions between this method and methods SC.1 (food) and SC.3 (other materials). In the case of SC.1, the use of purchaser price models will include emissions associated with long-haul transport of food from the producer to the in-community retailer. In the case of SC.3, these emissions are already included in the emissions factors provided in Table SC.3.1.

Second, the potential also exists for some amount of double counting with emissions estimated in Appendix D: Transportation and Other Mobile Emission Activities and Sources (see Method TR.2.C).

Third, many manufactured goods travel over very complex supply and distribution networks. The method provided below only estimates emissions associated with long-distance freight trips that end in a community. For many commodities, this will represent only a limited perspective of the freight impacts of materials used by that community. For example, a landmark study by Weber and Matthews (2008) found that for food purchased by the average U.S. household, the GHG emissions associated with transporting food from the final producer to the retailer were well less than half of all transport-related upstream emissions. Transport of seeds, fertilizers, other supplies, and raw food to processers and manufacturers contribute more to the carbon footprint of food than transport from the final producer to the store.

Even more significantly, for many goods, total freight impacts are small in comparison to emissions associated with production and manufacturing. This is illustrated in Table SC.4.1, which disaggregates emissions factors from Table SC.3.1 into three broad categories: manufacturing and process–related emissions, supply chain transportation emissions (upstream of the final producer), and emissions associated with transportation from final producer to retailer. Table SC.4.1 shows that for these product types, emissions from transporting finished materials into communities for use are often far smaller than other freight-related emissions, which in turn are again often smaller than non-freight manufacturing-related emissions.

Table SC.4.1
Upstream Emissions Factors for Select Materials, mt CO_2e/short ton

Material	Emissions Factor, mt CO_2e/short ton			
	Manufacturing and Process	Transportation Upstream of Final Producer	Transportation, Final Producer to Retailer	Total
Aluminum Cans	7.91	0.31	0.04	8.25
Steel Cans	2.83	0.32	0.04	3.19
Corrugated Cardboard	0.75	0.10	0.04	0.88
Newspaper	1.87	0.03	0.04	1.93
Medium-density Fiberboard	0.29	0.07	0.04	0.40

Sources: US EPA WARM tool (version #11), US EPA "Solid Waste Management and Greenhouse Gases: A Life Cycle Assessment of Emissions and Sinks" (2006). Numbers don't exactly match Table SC.3.1 due to rounding.

Similarly, Weber and Matthews (2008) identified that for all food-related emissions upstream of the average U.S. consumer, transportation from final producer to retailer contributes 4%, other transportation contributes 7%, retail/wholesale activities contribute 5%, and upstream processes (agriculture and food processing) contribute 83%.

If long-distance freight emissions are estimated, these important caveats should be considered, particularly when communicating results.

SC.4.1 Long-Distance Freight

- A report by the Bureau of Transportation Statistics (BTS) noted trucks are the preferred mode for shorter distance (<500 miles) freight, and rail for longer distance (>500 miles) freight (BTS, 2009).
- As many of the goods used within US cities are transported from an average of 500 miles (BTS, 2009), trans-boundary impacts from long-distance freight may also be important contributors of GHGs associated with cities.
    - The US National GHG Inventory reports that Trucks contribute 6% to the total US GHG emissions. As a result, this section provides guidance for accounting GHGs embodied in long-distance freight travel.
- GHGs from in-boundary truck transport are already accounted for through the guidance provided in Appendix D, Section TR.2.
- The US Economic Census is used as a proxy to track the amount of long-distance freight attributed to cities. The census data reports outbound activity (in monetary units) by the long-distance freight sector (NAICS 48412). Cities should use inbound long-distance freight data if available (e.g., regionalized input-output tables).
- The National benchmark for long-distance freight is $323 per capita (in 2002$).

  - Note, if using EIOLCA, expenditures must be converted from current year $ to 2002$, as the EIOLCA is built from the 2002$ US economy.
  - For this conversion one can use the BLS price inflation tool (http://www.bls.gov/data/inflation_calculator.htm)

SC.4.2 Long-Distance Freight Emissions Factor

- The life cycle EF for long-distance freight for all goods used in cities is obtained from the EIOLCA model. The EF for long-distance freight is estimated as 1.9 kg-CO_2e/2002$.

SC.4.3 Sample Calculation

- Annual expenditures towards long-distance freight by a community of 10,000 people are $300 per capita (in 2002$). The life cycle GHGs from long-distance freight for this community are computed as follows:

Life Cycle GHGs from long-distance freight = ($300/capita/yr)(10,000 people)(1.9 kg-CO_2e/2002$)(1 mt/1,000 kg) = **5,700 mt-CO_2e**.