Supplemental Background Information on
Oregon's Consumption-Based Greenhouse Gas Emissions Inventory (CBEI)
Prepared for the CBEI Project Review Workgroup by Oregon DEQ
September 23, 2010

DEQ has prepared this document to help Workgroup members prepare for the first Workgroup meeting (September 29). Some of the information contained herein will be covered in presentations and discussion on September 29. However, because some of this information is quite complex and likely new to some Workgroup members, members are invited to read this supplemental background information in advance.

Topics covered in this document include:

- A short introduction to greenhouse gas (GHG) inventories and how they're used
- A listing of DEQ's original objectives for developing a consumption-based emissions inventory for Oregon
- Clarification of differing uses of the term "consumption," including how "consumption" relates to "use," electricity, and materials
- An overview of life cycle analysis and a side note explaining the major differences between process life cycle analysis and input-output life cycle analysis
- An overview of the CBEI methodology
- An exposition of the difference between "CBEI" and "CBEI-LCA."

GHG Inventories and How They're Commonly Used

GHG inventories are commonly conducted at the scale of both organizations (such as a business or university) and communities (cities, regions, states, nations). Organizational and community inventories have several differences. This document focuses on GHG inventories at the scale of a community (such as a state).

At its most basic, a community GHG inventory is an accounting of the emissions of greenhouse gases that either originate within the community, or that the community otherwise exerts some influence over and/or claims some level of responsibility (although this responsibility could be shared with others). The concept of "influence" is often thought of as akin to "policy influence" (for example, through state laws or governmental programs) but may extend to include actions undertaken by residents and/or businesses located in the community.

There are several different scales of "communities," including local governments, state governments, and even nations. The accounting framework for national GHG inventories is mandated by the United Nations Framework Convention on Climate Change (UNFCCC) and its principal update, the Kyoto Protocol. This accounting framework is largely geographic in nature; nations account for the emissions that physically originate within their borders. As long as every nation follows the same accounting protocol, it allows for summation of national inventories into a global total.

State and local inventories are more complex. In the United States, the EPA has developed a "State Inventory Tool"(SIT) to assist in development of state-level GHG inventories. The SIT largely follows the geographic approach (sometimes called a "production-based approach") of the UNFCCC, counting all direct emissions that physically originate within a state.

Among these direct, in-state emissions sources, fossil fuel consumption for energy production, transportation, heating, and industrial uses dominate Oregon's inventory. However, emissions from a variety of other in-state sources are also included. These include carbon dioxide (CO_2) from industrial processes and waste combustion; methane (CH_4) from fuel combustion, natural gas and oil systems, enteric fermentation, manure management, landfills, and wastewater treatment; nitrous oxide (N_2O) from fuel and waste combustion, manure management, and agricultural soils; and other gases (HFCs, PFCs, and SF_6) from industrial processes.

Oregon's inventory has deviated from the SIT in one important regard. Rather than counting the direct emissions associated with in-state combustion of fossil fuels used to make electricity (e.g., burning of coal at Boardman), Oregon's inventory estimates the emissions associated with combustion of fossil fuels associated with generation of electricity *used* in Oregon. Some of these emissions occur in Oregon, while others occur in other Western states. This approach is sometimes referred to as a "consumption-based approach for electricity" (although the use of the word "consumption" in this context is not the same as in CBEI; see "Defining Consumption", below).

The rationale for this approach is summarized in Appendix 1 of The Governor's Climate Change Integration Group: Final Report to the Governor:

> "An emerging consensus is for greenhouse gas inventories, especially at the state or regional level, to attribute energy emissions to the jurisdiction in which the energy is consumed. Following this convention, the Oregon Department of Energy calculates emissions from electricity generation based on the carbon content of the regional mix of electricity that serves Oregon's electrical load. This approach is known as a 'consumption-based' inventory methodology.
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> In contrast, the federal government uses a 'production-based' inventory methodology which counts emissions from power that is generated within a jurisdiction's geographic boundaries (but not from the consumption of electricity). At the national level this approach makes sense. However, the "consumption based" regional approach better reflects carbon emissions in Oregon for the following reasons:
> 1) Oregon's second-largest utility, PacifiCorp, has most of its power generation out-of-state, and most of that is coal-fired.
> 2) Taking credit for hydropower generated for the Bonneville Power Administration from Columbia River dams, as it is allocated to Oregon in national inventories, does not reflect the way that electricity (and its associated emissions) is actually distributed in the region.
> 3) Using a 'production based' inventory as a means to measure policy actions at the state level can lead to misleading results. In effect, an action to reduce emissions only leads to an emissions reduction if the emissions are physically generated within state boundaries."

Oregon's inventory through the year 2004, and the current methodology, are provided in Appendix 1 of this report: http://oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf. Updated estimates of emissions for the year 2005 (the most recent year available) are provided in Appendix B of the Global Warming Commission's 2009 Report to the Legislature: http://www.keeporegoncool.org/sites/default/files/ogwc-standard-documents/09CommissionReport.pdf. (Updates through 2008 will be completed by the end of this year.)

At the local level, a wide variety of approaches have been used for inventorying GHG emissions. The most common approach is to use the Clean Air and Climate Protection Software (CACPS), developed by ICLEI, an international association of local governments working towards goals of sustainable development. This represents a *de facto* protocol, of sorts. However, while the inventory approach contained in CACPS is commonly used, many communities have deviated from it. ICLEI has recently initiated a project to develop a formal protocol for community inventories in the US. Workgroup member Josh Skov as well as several DEQ staff are involved in that project. Outcomes of DEQ's CBEI effort may inform ICLEI's protocol.

Community inventories are used in many ways, including but not limited to the following:

- To establish a baseline against which to set emissions reduction goals.
- To identify major sources of emissions that the community can influence, to identify trends in those emissions, and to inform efforts such as the development of climate action plans (reduction strategies).
- To measure change over time.
- To communicate to the public how the community contributes to emissions.

While all national inventories are summed to create a global total, the national inventory for the US does not rely on summing state inventories, and Oregon's inventory does not rely on summing local inventories. As such, inconsistencies in these inventories may be less of a concern.

DEQ's Objectives for this Consumption-Based Emissions Inventory Project

State and local governments, as well as businesses, media, and the general public, often base and/or describe greenhouse gas reduction efforts in the context of GHG inventories. In addition, inventories are used to define "baselines" and measure progress at reducing emissions.

Because emissions are caused by both production- and consumption-related activities, and because emissions caused by activities in Oregon occur both inside and outside of Oregon's borders, it can be challenging to capture all emissions is a single accounting framework. And yet, a comprehensive view of emissions can provide Oregonians with more complete information on how Oregon contributes to climate change, and opportunities to reduce greenhouse gas emissions. This expanded view might reveal opportunities to cost-effectively reduce greenhouse gas emissions that would otherwise go unnoticed or be de-emphasized. One approach is to supplement the traditional inventory with a consumption-based view of emissions.

Specifically, a consumption-based inventory allows for a deeper understanding of the ultimate drivers of emissions across all sectors of the economy. It can also improve understanding among consumers, businesses, and governments about how their choices effect both direct and indirect emissions, and can identify "hot spots" and unsustainable consumption patterns and trends.

Consumption-based inventories are also important for organizations working in the fields of sustainable consumption and materials conservation (including green building, waste prevention, and product stewardship).[1] Approximately 42% of GHG emissions in the U.S. are associated with the production, transportation, and disposal of materials.[2] Emissions are even larger if the impacts of imported goods are considered.[3] Many of these emissions are not included in state and local inventories, and when they are, are apportioned to other, broader categories such as "transportation" and "electricity use." Further, actions related to materials management in Oregon could reduce emissions from the perspective of the global economy, but increase emissions in Oregon (or vice versa). Understanding and accounting for the full, global nature of emissions associated with materials management in Oregon thus takes on importance.

The consumption-based approach also explicitly acknowledges the problem of leakage – the movement of emissions to other states or countries as production shifts from one region to another. The emissions from a relatively clean Oregon producer are included in Oregon's existing inventory, but the emissions from a dirty foreign competitor are not. As production shifts to countries with more carbon-intensive fuel mixes, worldwide emissions resulting from consumption activities in Oregon may increase, but the existing geographic-based inventory would report a decrease in emissions.

For these reasons, Oregon's Environmental Quality Commission directed DEQ in 2007 to further evaluate, and, as appropriate, work to integrate consumption-related emissions into inventory efforts.

In beginning this project in 2008, DEQ identified the following objectives:

- Estimate the greenhouse gas (GHG) emissions associated with the production of goods and materials in Oregon, and all consumption activities (including energy as well as goods and materials) in Oregon.
- For emissions associated with consumption in Oregon, disaggregate emissions by life cycle stage (production, transport, use, disposal) and geography (in-state, other domestic, non-domestic).
- Relate these estimates to the State's existing GHG inventory and demonstrate which emissions are already included, and which are not.
- Identify categories of consumption (including but not limited to goods and materials) that contribute the most to Oregon's consumption-based GHG emissions, both in absolute terms and as emissions intensities (high emissions per dollar spent).

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[1] Although it should be noted that pure consumption-based inventories do not present a full picture of the emissions associated with materials used in a community; see "Defining Consumption" below.
[2] US EPA, Opportunities to Reduce Greenhouse Gas Emissions through Materials and Land Management Practices, September 2009.
[3] Joshuah Stolaroff, Ph.D., for the Product Policy Institute, Products, Packaging, and US Greenhouse Gas Emissions, September 2009.

- Develop data sources and methodologies that are robust enough to permit consistent, persistent, and low-cost data collection and the ability to identify points of monitoring for future years.
- Document assumptions, methodologies, and data sources, enabling analysis in future years, and allowing other states and possibly local governments as well to replicate this effort.
- Identify additional data needs that would improve the reliability of these estimates in the future, thus establishing a potential research agenda.
- Present results in a manner that helps policy makers, the general public and others understand the relative impact of materials production- and consumption-related emissions, including a) the impacts of increasing/decreasing consumption of materials/products, b) the potential benefits of shifting from high-carbon to low-carbon goods and materials, and c) the impact of shifts between in-state, domestic out-of-state, and foreign production of materials/products that are consumed locally.

As part of this project, DEQ expected the analysis to answer some additional questions, such as:

- How do the production-based and consumption-based inventories compare against each other?
- How much of the emissions associated with in-state consumption occur in Oregon vs. the rest of the U.S. vs. other countries?
- Comparing similar products, is there a greenhouse gas benefit to consuming Oregon-made goods relative to goods made elsewhere in the U.S.? Relative to goods made in other countries? How large is this benefit, and how much of it is related to differences in production energy mixes vs. transportation requirements vs. other factors?
- How much of Oregon's consumption-related emissions are associated with different categories of consumption? For example, how do emissions compare between in-state consumption of food, other products, electricity, and heating fuels?

Because such an effort has not been undertaken before in the U.S., and given limited resources, DEQ has never expected that all of these objectives and questions will be equally satisfied in this current project. Further, certain methodological issues (treatment of land-use related emissions, for example) are being deferred entirely for future consideration.

Defining "Consumption"

The term "consumption", as used in DEQ's Consumption-Based Emissions Inventory, refers to what economists typically call "final demand". It represents purchases of goods and services (including energy) by households and governments. Also included are business purchases that are classified as investment or capital – typically, goods that are kept in inventory for more than one year, and not quickly passed on to another business. Other business-to-business expenditures are not part of "consumption", in order to avoid double-counting. This definition of "consumption", or "final demand", is consistent with the system of national economic accounting used by the US and throughout the world. [4]

[4] Net exports are not included in the definition of "consumption" in CBEI. Household consumption, investment expenditure, and government expenditure on goods and services, when added to net exports, represents Gross State (or National) Expenditure. Gross National Expenditure (GNE) is one way of measuring the market value of the nation's output. Gross National Product (GNP), the value of national incomes generated in the process of

A consumption-based emissions inventory attempts to estimate the greenhouse gas emissions resulting from consumption. As it relates to electricity, there are two important differences between CBEI and Oregon's existing GHG inventory.

- "Direct" vs. "indirect" emissions. Oregon's existing inventory includes emissions at the point at which electricity is generated, for example, the combustion of coal or natural gas. From the perspective of facilities that generate electricity, these are referred to as "direct" emissions. However, there are also "indirect" emissions associated with the supply chain. These include, for example, emissions associated with mining, crushing, cleaning, and transporting coal. CBEI includes both direct and indirect emissions.
- "Consumption" vs. "use". Oregon's existing inventory accounts for (direct) emissions associated with all electricity used in Oregon, including use by households and businesses. CBEI accounts for (direct+indirect) emissions associated with all electricity consumed in Oregon. This is limited to use of electricity by households and governments (for example, home lighting, school plug loads, etc.). Electricity use by businesses is not included, except when the electricity is used to satisfy "final demand" (consumption) in Oregon. For example, the emissions associated with electricity used to operate a hotel in Portland counts towards Oregon's CBEI when the hotel is satisfying "final demand" from Oregon households, but *not* when it is satisfying "final demand" from out-of-state visitors. Further up the supply chain, the electricity used by Intel to make semiconductors in Oregon counts towards CBEI when the semiconductors eventually satisfy final demand by Oregonians – either when Oregon households purchase them in a personal computer, or perhaps when they form part of a longer supply chain (for example, used in a computer that runs an automated production line that makes molded plastic in China for toys that are eventually purchased by households in Oregon).

It should be noted that consumption-based accounting does <u>not</u> identify the emissions associated with all <u>materials</u> used in Oregon. To continue the example above, when the Portland hotel purchases coffee, the emissions associated with making the coffee (regardless of whether production occurs in- or out-of-state) only count towards CBEI in proportion to the hotel's percentage of "final demand" that originates from Oregon consumers. The same is true of all other materials (as well as services and other energy) purchased by the hotel (towels, cleaning supplies, air filters, soap, etc.). In CBEI, the defining factor that determines whether an activity's emissions is included is whether or not the activity in question ultimately serves to satisfy final demand from Oregon households, governments, and business investments.

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production, is the second measure. While GNP is more commonly used, the value (in dollars) of GNE and GNP should be identical, in theory.

Overview of Life Cycle Analysis

Life cycle analysis (LCA) refers to the evaluation of emissions and/or environmental impacts associated with the full life cycle of a product or service. The phrase "life cycle" is typically divided into three stages: "upstream", which includes all resource extraction, supply chain, manufacturing, wholesale, and retail activities; "use" in which the consumer uses the product or service; and "downstream", related to end-of-life activities such as recycling, composting, or disposal. LCA provides for a comprehensive and holistic view of environmental impacts. While LCA typically considers multiple environmental attributes (or "impact categories"), such as cancer potential, ecotoxicity, and acidification, in this project we are concerned with just one: global warming potential, or the emissions of gases known to contribute to climate change. Amongst these, the primary gases are fossil-derived carbon dioxide, methane, and nitrous oxide.

There are two very different types of LCA: process LCA and input-output LCA. Process LCA is by far the most common, but since input-output LCA underlies the CBEI model, it is worth understanding the major differences between the two approaches.

Process LCA involves breaking the life cycle of a product or service into a series of inter-related "unit processes". For example, the unit processes involved in making a cookie include "mixing the ingredients", "greasing the cookie sheet", "pre-heating the oven", "baking the cookies", and "cooling the cookies". Each of these unit processes require upstream unit processes. For example, "greasing the cookie sheet" requires the production of both the cookie sheet and the margarine. "Mixing the ingredients" requires the production of each of the ingredients, each of which may require tens if not hundreds of other unit processes. In process LCA, the emissions associated with each unit process are identified. All of the unit processes are then linked together using principles of mass balance and allocation. In this way, the grand total of emissions associated with all unit processes can be understood. The unit processes are linked to each other typically in terms of mass (e.g. how many grams of milk are required to make the X grams of chocolate chips required to make 1 kg of cookies), and results can be expressed on a mass basis as well (e.g. grams of carbon dioxide equivalents per 1 kg of cookies). Process LCA is typically either "cradle-to-factory gate" (only upstream processes) or "cradle-to-grave" (upstream, use, and end-of-life).

In contrast, input-output LCA is typically limited to upstream processes. It draws on economic input-output models, which describe the economic inter-relationships between industries. Modern-day input-output analysis builds on the foundational work of the economist Wassily Leontief, for which he was awarded the Nobel Prize in economics in 1973. For example, an input-output model might illustrate that $1,000 of consumer expenditures in "clothing" translates into $A of inputs of polyester, $B of inputs of cotton, $C of inputs of wool, $D of inputs of packaging, $E of inputs of electricity, etc.. The inputs to produce $A of polyester, in turn, include $A1 inputs of natural gas, $A2 inputs of petroleum, $A3 inputs of rail transportation, $A4 inputs of organic chemicals, etc.. In this way, using linear algebra and an elegant construction referred to as the "Leontief inverse", all consumption activities can be traced back through the supply chains to their original production activities (as well as transportation). Traditional input-output analysis limits itself to understanding how a change in consumption or production in one sector of the economy leads to changes in production in all other sectors (and associated impacts, such as employment). Input-output LCA builds on this by assigning to each economic sector an emissions factor, expressed as direct (in-industry) emissions per dollar of economic output. The most popular input-output LCA tool is Carnegie Mellon's EIOLCA tool.

Major differences between process and input-output LCA include the following:

- Process LCA traces the flow of mass from one process to another; input-output LCA traces the flow of money from one industry sector to another.
- Process LCA allows for much greater granularity and refinement, including analysis of differences within individual sectors (e.g., organic vs. non-organic production of potatoes), while input-output LCA is only as granular as the number of economic sectors in the input-output tables (for the US, ~500), aggregating together not only organic and non-organic potatoes, but all fresh vegetables into a single category.
- Process LCA suffers from "cut-off error", the exclusion of impacts associated with unit processes that are "cut-off" from analysis, because of the assumption that these unit processes are not significant. For example, a process LCA of Rogaine might exclude emissions associated with minor production processes, as well as "home office" processes such as marketing and research. In some cases, cut-off error can be significant. Input-output LCA suffers from no-such cut-off error.
- Process LCAs tend to be relatively time-consuming and expensive. Input-output LCAs can be "quick and dirty", once the model is built.

Most of the LCA work done by DEQ (including our LCAs of e-commerce packaging, drinking water delivery, and residential housing) uses process LCA. For a project such as CBEI, process LCAs could have been used to estimate the emissions associated with each and every category of product consumed in Oregon, although this would require documenting consumption in terms of mass (tons of broccoli and fingernail clippers, board feet of softwood lumber, gallons of latex paint, numbers of cell phones), and having access to thousands of different process LCAs. In contrast, input-output LCA allows for a high-level view using a single, unified evaluation approach, at much lower effort and expense.

Overview of Oregon's Draft CBEI Methodology

DEQ selected the Stockholm Environment Institute US (SEI) to develop Oregon's consumption-based GHG inventory. SEI was selected from a pool of proposers through a competitive recruitment. Although all of the proposers offered slightly different approaches, all proposed using input-output LCA. This section summarizes SEI's approach. Additional details are described in a draft technical report.

SEI's work is divided into four basic tasks, as follows:

1. Develop an EXCEL-based model to assess consumption in Oregon and the embedded greenhouse gas emissions from both domestic and international production.
2. Estimate and assess emissions associated with consumption.
3. Document methodology, via the development of a technical report.
4. Develop a "public-friendly" summary report. The first draft of this summary report is what was transmitted to Workgroup members on September 16.

To allow for comparison against the current Oregon inventory, all modeling is being conducted for the year 2005.

The model itself consists of several modules, summarized as follows.

First, SEI identifies estimates of consumption expenditures in Oregon. Consumption is divided into four groups: household, investment, state/local government, and federal government. (Federal government consumption is limited to spending in Oregon on federal government operations, not including transfer payments to the state, local governments, or individuals [e.g., social security checks]. It does not include Oregon's "share" of federal operations, such as military and international affairs.) The source of this data is IMPLAN, a leading economic modeling software product that is widely used by economists, including those in industry, academia, and at other state agencies. IMPLAN provides for Oregon (and any geographic area down to the level of a ZIP code) estimates of consumption across roughly 500 industry sectors.

IMPLAN also provides an input-output model of both Oregon's economy and the larger U.S. economy, developed using data from the U.S. Commerce Department's Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, and other sources. These models track the economic inputs into each industry sector from all other industry sectors. IMPLAN further estimates, for each of the sectors, the proportion of consumer spending which remains in-state, flows to other states, or flows to other countries. This is used to build a "multi-regional input-output model" (MRIO), tracing the flow of Oregon's consumption (in dollars) to economic (production) activity in each of these three regions of the world.

The economic activity for each industry sector in each region is then related to estimates of emissions intensities (emissions per dollar) for each sector and each region. Emissions intensities for the U.S. are derived from federal Energy Information Administration and EPA data. Emissions intensities for production in Oregon are derived from Oregon's traditional GHG inventory. Non-domestic emissions are based on research conducted by SEI and the Center for International Climate and Environmental Research (CICERO), based on underlying data developed by the widely-used GTAP (Global Trade Analysis Project) model of international trade.

Emissions from in-state use of products are already included in Oregon's greenhouse gas inventory, but these emissions are not disaggregated by product category. SEI estimates use-phase emissions for different categories of products used in Oregon (automobiles, appliances, etc.), drawing on a variety of data sources.

Finally, SEI estimates emissions associated with solid waste disposal, based in part on DEQ's existing model of landfill/incinerator emissions by material type, and a cross-walk table to relate material types to individual product categories.

Upstream, use-phase, and downstream emissions are then summed together for a grand total.

“CBEI” vs. “CBEI-LCA”

There are two fundamentally different methods of evaluating and portraying results in a consumption-based emissions inventory. SEI refers to these as “CBEI” and “CBEI-LCA”.

“CBEI” assigns emissions to those sectors where the direct emissions occur. “CBEI-LCA” assigns emissions to those sectors where the original act of consumption (final demand) occurs. To illustrate the difference, consider the provision of clothing. When a household purchases clothing, it results in emissions in the clothing industry itself (where clothing is actually sewn and assembled) as well as a host of supporting industries, such as electric utilities, manufacturers of polymers, dyes, buttons, threads, zippers, and packaging, growers of cotton, and even attorneys, advertising firms, and computer makers. In CBEI, all of these emissions are assigned to their respective industries; only the direct emissions at the clothing factories are called “clothing”. In CBEI-LCA, all of these emissions are rolled together and assigned to “clothing”.

In contrast, consider all of the other consumer activities that can cause clothing to be produced. In addition to direct purchases by consumers, consumers might visit a doctor; some portion of doctor’s fees go to purchase scrubs worn by medical staff. Consumers might stay at a hotel; again, some portion of hotel fees go to purchase housekeeping and maintenance staff uniforms. Consumers might also purchase a car that contains microelectronic equipment. Some (albeit very small) portion of car purchases go to pay for the production of garments worn in clean rooms where semiconductors are made. In CBEI, the direct emissions from the clothing industry associated with making all of these different clothes would be assigned to the “clothing” sector, even though the consumer caused them through doctors visits, hotel stays, and a car purchase. In CBEI-LCA, the emissions associated with producing each of these different garments would be assigned to the sector where the consumer demand first occurred (e.g., doctors offices, hotels, and automobiles).

The model created by SEI for DEQ reports results using the “CBEI” framework. Certain results in the summary report represent the “CBEI-LCA” perspective. DEQ is currently amending its contract with SEI to provide for the model in both CBEI and CBEI-LCA mode.