The Role of Green Electricity Purchases in Reducing Commercial/Institutional Entity's Carbon Footprint

Extended Abstract #66

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INTRODUCTION

For commercial or institutional entities such as office-oriented businesses and universities, electricity consumption represents the most significant source of their carbon footprint (total greenhouse gas (GHG) emissions resulting from products or activities). As a way to reduce their carbon footprint, some of these entities are voluntarily reducing their electricity consumption by implementing energy conservation measures and/or purchasing renewable electricity from their utility, which ensures that the purchased amount of electricity came from renewable sources. Although reducing the impacts from direct electricity use ("Scope 2" emissions, as defined in the World Resources Institute/World Business Council of Sustainable Development's GHG Protocol[1]) is a good way to reduce the carbon footprint, it does not address the emissions from indirect electricity embedded in the entity's supply chain ("Scope 3" emissions), which can be a significant part of the entity's total footprint. While it is straightforward to quantify Scope 2 emissions and the reduction from taking actions, the size and relative proportion of Scope 3 electricity emissions are not apparent unless the entity conducts a full carbon footprint study that captures most of its indirect emissions. On the other hand, government implementation of a Renewable Portfolio Standard (RPS), which mandates the amount of renewable energy that electric utilities must carry in their portfolio, would reduce the impacts of electricity within the political jurisdiction and cover parts of the entities' indirect supply chain. With a RPS, even if entities take no voluntary initiatives to reduce consumption or lower carbon intensity of their electricity, they will still see a carbon footprint reduction from their direct electricity as well as indirect electricity consumed by their suppliers located within the same political jurisdiction.

To understand the relative effects of reducing impacts of direct and indirect electricity in commercial/institutional entities' carbon footprints, this work utilizes an economic input-output life cycle assessment (EIO-LCA) method and examines the carbon footprint profile of an "averaged" entity in selected industries. We address the following questions: (1) What portion of a commercial/institutional entity's total footprint can be reduced by direct energy conservation or renewable electricity purchases? (2) Besides direct electricity use, what portion of an entity's indirect carbon footprint can be potentially reduced by a RPS implemented at the state and federal levels? (3) How much carbon footprint reduction can an entity see if it chooses upstream supply chain located in a state with lower electricity carbon intensity? Using California as a case study, we parse out the electricity portions of commercial/institutional entities' direct and upstream indirect supply chains by political jurisdictions. The model analysis looks at "averaged" commercial/institutional entities that use "averaged" inputs and materials in their direct and upstream supply chains. In reality, each entity's carbon footprint profile is unique and may not be exactly the same as the "averaged" entity in the industry, but this analysis can provide high-level insights that are useful for individual entities to identify strategies to reduce their carbon footprint from electricity.

METHODS

Economic Input-Output Life Cycle Assessment Model

The methods used in this work are based on economic input-output analysis,[2] a well-established method originally formulated by Wassily Leontief in 1936 to aid manufacturing planning.[3] In their original applications, these established methods and Carnegie Mellon University's Economic Input-Output Life Cycle Assessment (EIO-LCA) model utilize national-level industry-average data. Using the national-level model as the foundation, we constructed a multi-regional input-output (MRIO) model at different geographical scales: California, rest of the U.S. (RUS), and rest of World (ROW). More detailed treatment of the fundamental methods can be found in other published literature,[2-5] but a brief overview of the methods is described in this section.

At the heart of the model is the assumption that the total environmental impacts from industrial and economic activities are roughly proportional to the economic output (in dollars) of the activities. Using linear algebra common in the economics literature,[4] the model estimates all purchases and activities in a supply chain leading up to final manufacture in an industry. When the economic IO model is augmented with environmental information in matrix form, it estimates upstream life cycle environmental impacts of production activities by any sector in the economy. The basic IO model derives the total economic purchases across the supply chain of an economy required to make a desired output. Once the supply chain is calculated, environmental emissions can be estimated by multiplying the output of each sector by its environmental impact per dollar of output using the following equation:

$$\mathbf{b} = \mathbf{R}\times(\mathbf{I}+\mathbf{A}+\mathbf{AA}+\mathbf{AAA}+\ldots)\times\mathbf{y} = \mathbf{R}\times(\mathbf{I}-\mathbf{A})^{-1}\times\mathbf{y} \qquad \text{Equation. 1}$$

where
b = the vector of environmental burdens (e.g., GHG emissions for each production sector)
R = a matrix with diagonal elements representing the emissions per dollar of output for each sector (i.e., GHG emissions in $MTCO_2e$/ $1 Million in this case)
I = the identity matrix (a table of all zeros except for the diagonal entries containing a 1)
A = the direct requirements matrix (with rows representing the required inputs from other sectors to make a unit of output)
Y = the vector of desired production or "final demand"

The MRIO model is constructed in several steps. First, the domestic and import portions of the original national EIO-LCA model are separated using data compiled by U.S. Bureau of Economic Analysis.[6] Second, a proxy data set for economic activities is identified to provide the basis for separating production and consumption in California from the rest of the US. Third, we used a technique developed by input-output researchers (to estimate economic activities as proportion of total needs at regional level in the absence of survey data) to allocate California and RUS supplies that are used to meet California demands. Fourth, the Employment Ratio Method is used to allocate California and RUS supplies that are used for industry demands in the RUS region. Finally, all the components of the MRIO model are incorporated into a multi-regional A matrix in Equation 1.

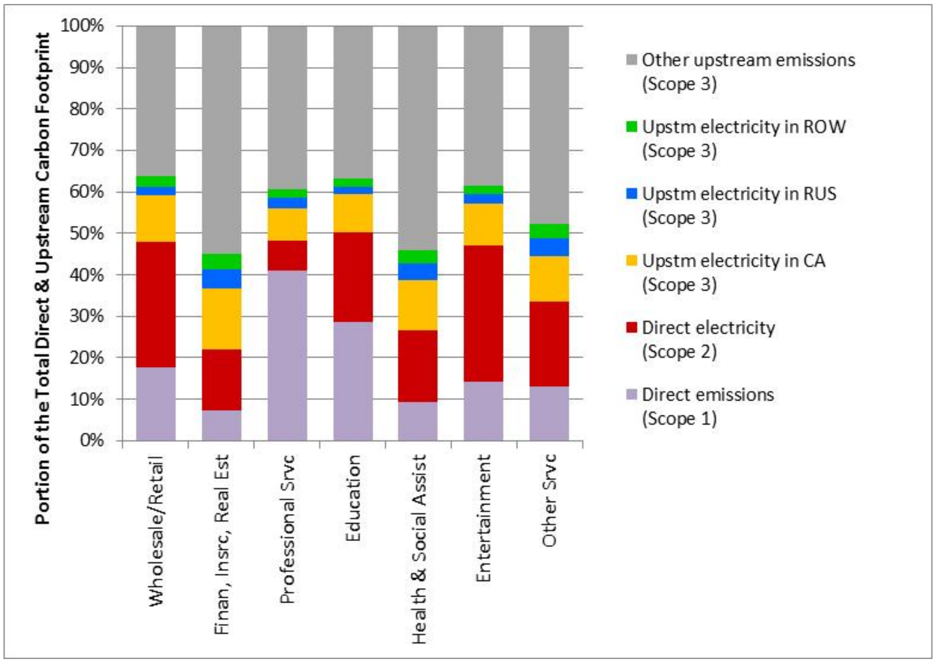
The model contains several assumptions. Although region-specific environmental vectors can be constructed, for the purpose of estimating the portions of supply chains attributed to electricity, US-based emissions factors based on the EIO-LCA model are assumed for all regions in this study with the exception of the power generation sector. The carbon intensity of California electricity grid is 40% lower than the US average in its mix of electricity generation portfolio.[7,8] For ROW, although previous research suggests that the average mix of imports into the US may have a higher CO_2 intensity than domestically-made goods for some commodity classes, because it is very difficult to compare the emission factors across countries due to exchange rates, lack of data, and other issues, the US average CO_2 intensity is assumed for this analysis.[9] Finally, the model assumes that businesses in California will meet their demands for input materials and goods using in-state supplies first before importing from out-of-state sources.

RESULTS & DISCUSSIONS

Using the MRIO model, we isolated by geographical regions the portions of supply chain attributed to electricity for the selected industries. Although results are available for more detailed sectors in the North American Industry Classification System (NAICS), they are too numerous to show at once; therefore, the results are grouped into 7 broad industry groups for presentation in this paper. Variations in carbon footprint profiles are expected among the detailed sectors within the same industry group, but reviewing the results at the broad industry group level can still shed interesting insights on the trends in carbon footprint profile among similar sectors.

The model results from the perspectives of a subset of California commercial/institutional entities are shown in Figure 1. The portions of direct and upstream footprint by geographical regions are shown as stacked bars. The "Upstream electricity" stacked bars represent the life cycle impacts of upstream Scope 3 electricity that are summed across all tiers of upstream suppliers in a given region. As can be seen in Figure 1, from the perspective of California commercial/institutional entities, electricity embedded in the supply chains are approximately 20-45% of the total footprint. Of those, direct electricity consumption makes up 8-33% of the total footprint, while indirect electricity (upstream Scope 3) occurred in California accounts for another 10-15%. Additional upstream Scope 3 electricity occurred in RUS and ROW, and they can range between 1% and 4% in each region. If these entities take initiatives to reduce the impacts of their direct electricity use, e.g. by implementing energy efficiency measures or purchasing renewable electricity from their utilities, they can directly reduce their total carbon footprint by up to 20-45%.

Figure 1. Portion of supply chain attributed to the life cycle of transportation fuels and electricity, from the perspective for California enterprises



If they chose to take no initiative to reduce their electricity footprint, the state's RPS will still have an effect on reducing the emissions from direct electricity and upstream electricity in California. For example, for the wholesale/retail sector group, the direct electricity consumption and upstream Scope 3 electricity occurred in California together make up of 40% of its total footprint. With a 10% incremental increase in RPS in California, these entities' total footprints can be automatically reduced by 4% (40%×10%) without them taking any actions. In other words, the amount of entity footprint reduction from a 10% higher RPS state-wide is equivalent to the entity making only 4% reduction in its direct electricity consumption or carbon intensity. In practice, business entities can easily achieve 4% reduction because they have many energy conservation measures at their disposal. The process of purchasing renewable electricity through its utility is also matured enough that the desired amount of renewable electricity can be secured without much difficulty.

These model results also illustrate the effect of a national RPS policy on California entities' carbon footprint. In the selected industries' carbon footprint profiles, upstream Scope 3 electricity occurred in RUS makes up a small portion (less than 4%) of their total footprints (although the actual number may vary depending on individual entity's chosen supply chain). This suggests that business entities should not rely on the implementation of a national RPS for reducing their total carbon footprint (although a national RPS is nevertheless a good policy for the nation). Also, because the carbon intensity of California electricity is 40% lower than the rest of the nation, if business entities move their out-of-state upstream supply chains into California, they will also see a lower supply chain footprint embedded in their total carbon footprint.

SUMMARY

Using a MRIO model with California commercial/institutional entities as a case study, we showed the geographical distribution of life cycle impacts of electricity embedded in averaged entities' upstream supply chains. Energy-conscious businesses can directly reduce a significant portion of their carbon footprint by implementing energy efficiency measures and/or purchasing green power. Government implementation of a RPS can also reduce the impacts of direct and indirect electricity in their carbon footprint. Businesses interested in reducing their life cycle carbon footprint can also consider moving their supply chains into California, where the average carbon intensity of electricity is significantly lower than rest of the nation.

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