Research assumptions, methodologies and analytical results for a low-carbon diet calculator for public education

A project conducted for the Bon Appétit Management Company Foundation

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1. Introduction

The purpose of this report is to outline methods and results from a study to provide estimates of greenhouse gas (GHG) emissions associated with the production, distribution and cooking of food items used in Bon Appétit Management Company's Low Carbon Diet program that was announced by the company in April 2007. As part of that program, which includes procurement, operational and educational elements, the Bon Appétit Management Company Foundation is developing a Low Carbon Diet Calculator the goal of which is to (1) serve as a tool to educate the general public about how their informed food choices can be one of many personal choices to lower their carbon footprint, and (2) catalyze future research, especially for North American production systems, to populate this tool with a more robust set of food options. The purpose of this document is to outline the methods and assumptions of the work undertaken.

2. Review of Previous Work

At the outset of this project, the research team intended to build upon the literature, as well as work previously completed by various consultants on the greenhouse gas emissions associated with the primary production of each food item. A careful review of the primary production values for various food items, however, raised several concerns about data quality, the usefulness of the data and concerns about methodology. The key concerns are outlined below:

a. Basing GHG Emissions Solely on the Amount of Energy Inputs

The greenhouse gas emissions associated with the primary production of various food items are frequently calculated solely by considering primary energy input values. This is a flawed approach, as the amount of primary energy on its own tells nothing about how that energy was generated, and the greenhouse gas emissions profile is entirely dependent on the mode of energy production. For example, the greenhouse gas emissions associated with the production of 100 MJ of primary energy will be very different if it is generated by burning coal as opposed to hydroelectricity or by combustion of diesel. In short, it is imperative to know the source of the energy in order to calculate greenhouse gas emissions. Several software models were not transparent enough to determine how the model converts the energy inputs into GHG emissions. If done in the absence of information on the source of energy (i.e. hydropower, fossil, etc.), the values generated could potentially be very poor approximations of reality.

b. Study Parameters and System Boundaries

Many analyses have generated values for livestock production systems (e.g. beef, pork, poultry, eggs, etc.) from the ratios of industrial energy inputs to caloric energy outputs as described by Pimentel and Pimentel in their 1996 book [1] and journal article from 2003 [2]. For example, they state that for lamb, 57 kcal of fossil energy inputs are required to produce 1 kcal of animal protein. One previous analysis we found simply took this value and converted it to kcal per oz in order to determine the primary energy inputs for the production of lamb. If one is going to apply these ratios to develop greenhouse gas emission profiles for these production systems, it is essential to know the system boundaries for the source study. For example, what processes are included in the Pimentel analysis of lamb production? Were similar system boundaries used in the Pimentels' analysis of beef production? Were GHG emissions from livestock, fertilizers and wastes included? Was the processing stage included? If these parameters are not known, then it is not appropriate to generate and compare greenhouse gas emission intensities for these production systems from the industrial energy to protein energy ratio. More information is required to determine if data from these studies are complete, reasonable, and comparable.

Secondly, while these ratios from Pimentel and Pimentel may provide some sort of estimate on the amount of industrial energy required to produce a given food item, the value for primary energy inputs does not provide any specific information on what form this energy takes and how it was generated. The above value of 57 kcal of fossil energy includes energy inputs throughout the production process, including production of forage crops, production of pesticides and fertilizers, operation of farm equipment, etc. The greenhouse gas emission profile of each of these processes will differ, and these differences must be accounted for in order to get an accurate estimate of the greenhouse gas emissions associated with the production of meat from lamb.

c. GHG Emissions from Agricultural Systems

The GHG emissions data generated from the energy input data provided by many carbon emission consultants are inadequate with respect to agricultural systems. The use of primary energy inputs to calculate greenhouse gas emissions is grossly inaccurate for agricultural systems where emissions of methane and nitrous oxide from enteric fermentation, wastes, and fertilizers can sometimes account for up to 80% of greenhouse gas emissions. In fact, one expert went so far as to say that a "carbon footprint" inadequately describes agriculture, which in fact has a "carbon-nitrogen footprint" as a result of the emissions from fertilizer inputs. [3] To not account for these emissions in any analysis of the greenhouse gas emissions associated with agricultural systems is a major error.

d. Input-Output Analysis

Another approach to explain the carbon emissions of foods is input-output analysis. The appeal of this set of data is clear because it provides a lot of answers for many food products, including packaged foods. Unfortunately, these answers are grossly aggregate and not useful for the project at hand. This approach effectively makes an economic allocation of the impacts of food production, whereas allocation on energy or biomass is preferred for food systems.

3. Methods Used

There are two potential paths to take in order to develop a reasonable approximation of the GHG emissions associated with the production of Bon Appétit food items. The first option is to conduct primary research on the inputs and outputs of the specific production systems that provide food items within Bon Appétit cafes. This would involve the collection of new data on the various production systems (e.g. poultry, beef, wheat, milk, etc.) with regard to energy inputs and associated GHG emissions at each life cycle stage of the production system. While this approach would provide the most rigorous and defensible results, and we would like to be able to do this in the future, it would also require considerable time and resources – more than are currently available. In addition, because Bon Appétit has a robust program for purchasing a large percentage of food products from local and regional primary suppliers across the country, the sheer number of variations would be difficult to capture.

We chose a second approach, which is to conduct a literature review that is focused on studies which have already calculated GHG emissions for the various food production systems that provide clear details on system boundaries, modes of energy production, and clear allocation decisions. The current focus is on Life Cycle Assessment studies, as these studies are generally more comprehensive and generally include non-energy related GHG emissions for agricultural systems (including, for example, methane from enteric fermentation).

It is important to note that data for a number of important food products were derived from a Danish LCA study that uses the so-called “consequential” approach to allocation, which does not conform to current International Standards Organization’s standards. Ayer et al. [3] illustrate the sensitivity of LCA results, including greenhouse gas emissions, of adopting different allocation strategies.

Outside the scope of this study is a remedy of the problems associated with assembling data from a wide variety of sources that have employed different approaches and solutions with respect to system boundaries, while more or less following LCA methodological guidelines (such as whether infrastructure is included or excluded, and how impacts are allocated amongst co-products).

We then used the production data in an analysis of the supply chain (section 4.b. below) and some standard Bon Appétit Management Company cooking processes (section 4.c.) to produce a comprehensive set of emission estimates that can be combined in a range of recipes.

Finally, data for several ingredients are not available, meaning that in order to calculate the per-recipe GHG emissions, some assumptions have to be made. For example, one could ignore the emissions associated with the missing ingredients entirely, which would result in an underestimate of the actual recipe's emissions. Alternatively, one could apply the average emissions associated with all food items documented in this study, or with the subset of ingredients used in the recipe, to those ingredients for which no estimates are available. It is not clear if this would result in an under- or overestimate in the respective cases. We therefore recommend, for consistency, using the former approach, which is to ignore the unknown emissions and, therefore, report an underestimated number.

4. Results

a. Production Data Literature Review

An important initial result of the literature review is that there have been very few comprehensive studies carried out on the GHG emissions of specific U.S. food production systems (e.g. emissions per tonne of poultry, per tonne of beef, etc.). Most of the life cycle analyses and GHG analyses of food production systems that have been done to date are based on European production systems. This leaves some uncertainty with regard to how comparable these data are to U.S. production systems and, as such, care must be taken in any instances where European data are used to provide approximations of GHG emissions from U.S. production systems. In some cases the production systems and regional conditions may be very similar. (Many studies, in fact, cite USDA data.) In other cases, however, they may not, and thus care must be exercised when analyzing the result of European studies in the North American context. Our method essentially “transplanted” farms and other food production technologies and processes from Europe to the US, thus remaining agnostic about the specifics of actual US production systems.

It is also the case that while a number of comprehensive studies have been conducted on European production systems, the number is fairly limited and the variety of products considered is also quite limited. The majority of the studies are focused on primary food items such as milk, beef, pork, and some vegetables. Few, if any, studies have been conducted on heavily processed foods such as cheese, butter, yogurt, pasta, hot dogs, soda pop, and candy. A great deal of the specific GHG emissions data, therefore, simply does not exist in the literature. We can only generate data for transportation emissions in these cases, which limits the global warming potential (GWP) of these figures.

Many of the LCA studies included in this analysis report some transportation emission impacts, including final product transport to distributor and retailer in some cases. For *some* products, we have removed the final transport emissions from the original LCA results in order to avoid double counting that component. But there are still many products for which we do not have the detailed results to enable this operation—in some cases, it is therefore possible that the final product transport emissions are counted twice (using different assumptions/scenarios). Furthermore, for *some* products, we have replaced emissions from electricity with equivalent emissions based on U.S. average electricity generation. To some small extent, this brings the results closer to U.S.

conditions. But there are still many other location-specific production details embedded in the original LCA results that may or may not be applicable to the U.S. Both these adjustment steps are our initial attempts at mapping the largely European data to North American conditions.

It is useful to reiterate that the studies reviewed vary quite widely in terms of geographic scope and system boundaries and, as a result, the emissions values are going to vary from production system to production system. This variability can often be quite large. Depending on how the study was done, the numbers can vary widely, implying that extreme caution should be used in the interpretation of the values as they are combined with the subsequent analytical results into whole recipes for the low carbon diet.

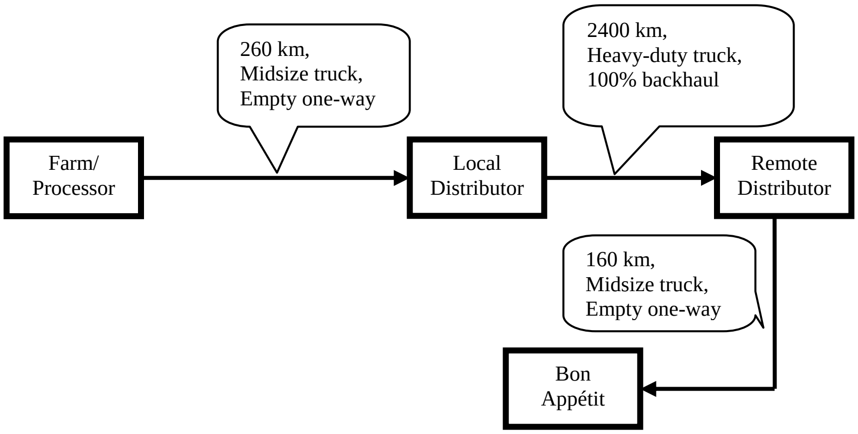
b. Food Supply Chain Emissions Analysis

Using the production values found in the literature (4.a.), we then combined them with supply-chain emissions resulting from the distribution phase. The final carbon footprint figures, in grams of CO2-eq per ounce of each food commodity, are in the worksheet labeled “4. Total Carbon Footprint”:

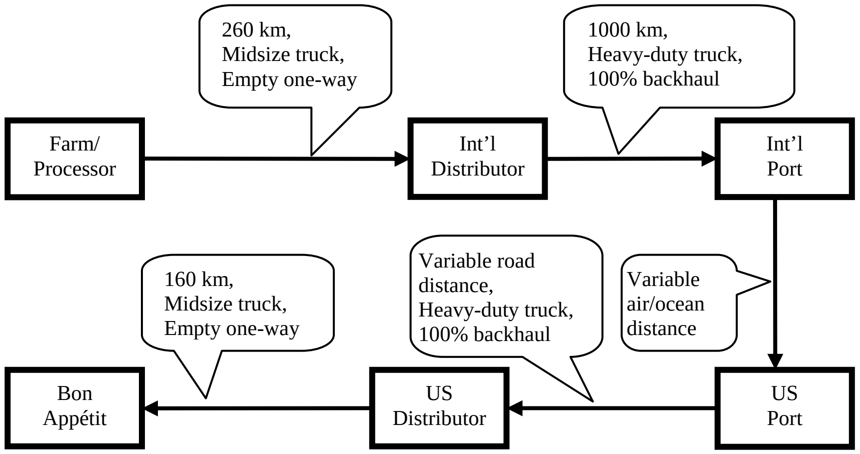
- Column D: Total carbon footprint assuming all sources are domestic and product transport by <u>road</u>.
- Column E: Carbon footprint variations for seafood, assuming each item is sourced in Asia (using Bangkok, Thailand, as a generic Asian location) and transported by <u>ocean</u>.
- Column F: Carbon footprint variations for seafood assuming each item is sourced in Asia (using Bangkok, Thailand, as a generic Asian location) and transported by <u>air</u>. Also includes a carbon footprint variation for strawberries, assuming they are sourced in South America (using Santiago, Chile, as a generic location) and transported by air.

The analysis is based on the following generic national and international distribution networks, and done using CargoScope. It replaces the regional sourcing considerations discussed in section 5 of the previous version of this report.

<u>Domestic distribution:</u>



International distribution:



We used the following assumptions and specifications for our analysis:

- **Fuel/Energy characteristics:**
    - Key data:
        - Diesel: 0.0371 GJ/Liter ; 2745.77 g CO2/Liter [4]
        - Electricity (US avg.): 0.0036 GJ/kWH ; 606 g CO2/kWH [5]
- **Transportation characteristics:**
    - Key data:
        - Midsize truck, Class 6, diesel (GVW: 19501-26000 lbs):
            - mpg = 7 ➔ 0.3359 L/km [6]
            - Typical capacity: 6250 kg ; 39.02 cu-m [7]
        - Heavy-duty truck, Class 8, diesel (GVW: > 33000 lbs):
            - mpg = 5.7 ➔ 0.4125 L/km [7]
            - Typical capacity: 17240 kg; 107.62 cu-m [7]
    - Key Assumptions:
        - Midsize trucks used for distances of < 500 km one-way, with trucks typically running empty in one direction
        - Heavy-duty trucks used for distances > 500 km, with trucks typically used productively in both directions
        - Refrigeration increases fuel use during transport. It depends on the refrigerated space (entire truck, or typical cargo container), the duration of transit, and the type of refrigeration (frozen, standard refrigeration, just cooled, etc.).
        - Trucks are assumed to be filled by weight – ignoring product density and assuming that full weight capacity of trucks can be utilized for each product type or mix of products transported by a truck on any

route. This assumption applies to both less-than-truckload (LTL) and full-truckload (FTL) shipments.

- **Refrigerated warehousing characteristics:**
    - Key data:
        - Energy Star formulas for maximum (avg.) energy use in commercial refrigerators [8]:
            - Refrigerators: (0.1 * V + 2.04) kWH/day, V = internal volume in cu-ft
            - Freezers: (0.4 * V + 1.38) kWH/day
    - Key assumptions:
        - All warehouse energy use assumed to be electricity.
        - Warehouse space assumed to be fully utilized.
        - Assume refrigerators or freezers with 300 cu-m capacity – just for convenience in calculations – doesn't affect final normalized power consumption below.
        - Refrigeration capacity allocated and used by volume occupied – so product density (including allowance for packaging and empty space) comes into play.
        - All products spend 2 days in storage before reaching Bon Appétit Management Company sites.
    - Derived data based on Energy Star formulas:
        - Refrigerators (for fruits, vegetables and dairy products):
            - Power consumption =44.22 kW
        - Freezers (for meat, ice cream, etc.):
            - Power consumption = 176.61 kW
        - For products requiring only "cool temperatures" (dry goods such as cereals, pasta, rice, bread), assume power consumption to be 25% of full refrigeration:
            - Power consumption = 11.06 kW

- **Other supply-chain assumptions:**
    - Representative data for product density in storage and transit for *product categories* – extrapolated from data for specific food products provided in [9] and dependent largely on water content – with added 25% additional space for packaging materials and air:
        - Vegetables: 600 kg/cu-m
        - Fruits: 600 kg/cu-m
        - Milk: 825 kg/cu-m
        - Cheese: 450 kg/cu-m
        - Meat and Seafood: 750 kg/cu-m
        - Bread: 135 kg/cu-m
        - Grains, flour: 550 kg/cu-m
        - Eggs: 600 kg/cu-m
        - Oil: 740 kg/cu-m

    - Ketchup: 825 kg/cu-m
- For each food commodity, we are using total (lumped) emissions for all production and processing steps, taken from LCA studies. Therefore, the supply-chain analysis has been done without modeling any details of the production/processing steps, and then the transport/storage results have been combined with the production emissions in the accompanying Excel spreadsheet.
- All meat and seafood items are assumed to be frozen in transit. This is likely to be true for road and ocean transport, and less likely for air transport. In the case of air transport of fresh seafood, this slightly overestimates the transport emissions (but this error is negligible compared to the actual air transport emissions).

c. Cooking Appliance Analysis

The accompanying spreadsheet contains an analysis of CO_2 emissions from energy inputs in the operation of selected models of a range top, a convection oven and a fryer. The range top uses electricity; the other appliances use natural gas primarily and some electricity to operate the controls.

The following specific models are included in the analysis:

- Vulcan-Hart Induction Range Top (2.5 kW)
- Vulcan-Hart Induction Range Top (5 kW)
- Vulcan-Hart VC4GD Gas Convection Oven
- Frymaster H55 Gas Fryer
- Wood Stone Fire Deck 6045 Gas-Fired Oven*
- Cleveland KGL-80-T Gas-Fired Kettle*

The "Cooking Emissions" worksheet contains the tabulated results, calculated from performance reports published by the Food Service Technology Center for each appliance and emission factors published by the U.S. Energy Information Administration. For electricity, we used a U.S. average emission factor, since Bon Appétit is not looking for regional variations at present. All emissions results in this worksheet are in grams of CO_2 per minute of operation.

The "Usage Examples" worksheet shows how to use the emissions figures from the previous worksheet to compute total CO_2 emissions for various cooking sequences and scenarios. All example results in this worksheet are in Kg of CO_2 for the total operation of the appliance.

5. Summary

The points associated with each food choice, then, can best be described as 'representational' of the best available published and peer-reviewed scientific papers outlining the GHG emissions of agricultural and other food production systems. Though

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* Electric power consumption not available

the numbers suggest a high degree of specificity, this is the result of combining several factors – observed production practices, transportation, cooking and portion assumptions – and adding them. A tomato grown in an especially hot climate with significant irrigation needs, a high degree of fossil fuel energy used to provide that irrigation, and far away from a port to which it must be delivered to market, will have a different specific number than a tomato grown and transported with different parameters. The number we use for both is the same because the variety of methods are not widely studied or yet available. The numbers given here, however, demonstrate a reasonable and observed difference between different major food categories (e.g. animal proteins versus plant foods) and, thus, represent a valuable educational tool for users seeking that broad level of knowledge.

6. References

[1] Pimentel D. and M. Pimentel. 1996. Food, Energy and Society: revised edition. University Press of Colorado, Niwot, Colorado, USA.

[2] Pimentel D. and M. Pimentel. 2003. Sustainability of meat-based and plant-based diets and the environment. American Journal of Clinical Nutrition, Vol. 78, No. 3, 660S-663S, September 2003

[3] Williams, A.G., Ausley, E. and Sandars, D.L. 2006. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra.

[4] Nathan W. Ayer, Peter H. Tyedmers, Nathan L. Pelletier, Ulf Sonesson and Astrid Scholz. 2007. Co-Product Allocation in Life Cycle Assessments of Seafood Production Systems: Review of Problems and Strategies. Int J LCA **12**(7): 480-487

[5] GHG Protocol – Calculating CO_2 Emissions from Mobile Sources; http://www.ghgprotocol.org/DocRoot/7NmWvnZLTBdCB73po4tL/co2-mobile.pdf

[6] Energy Information Administration – Voluntary Reporting of Greenhouse Gases Program – Average Electricity Factors by State and Region; http://www.eia.doe.gov/oiaf/1605/ee-factors.html

[7] Dept of Energy, EERE - Transportation Energy Data Book, Edition 26, 2007; http://cta.ornl.gov/data/index.shtml

[8] R. Pirog, et al, “Food, Fuel and Freeways”, 2001; http://www.leopold.iastate.edu/pubs/staff/ppp/

[9] Energy Star – Commercial Solid Door Refrigerators and Freezers; http://www.energystar.gov/index.cfm?c=commer_refrig.pr_proc_commercial_refrigerators

[10] USDA – National Nutrient Database for Standard Reference http://www.nal.usda.gov/fnic/foodcomp/search/