Case: Are Locally-Produced Foods Less Energy-Intensive than Imports?

Using CargoScope to Compare Energy Usage for Local and Imported Apples

It may seem natural to assume that food produced nearby will automatically be less energy intensive than more distantly sourced counterparts, as there is less distance to travel. This assumption is the basic premise behind "Food Miles" labeling. However, many other factors than just pure distance may come into play, such as transport mode, storage, yield loss issues and other such differences. We attempt to illustrate how such aspects may affect the energy intensity associated with supplying apples for consumption, inspired in part by research done by Milà i Canals et al. (2007).[1]

Apples are a widely-sold fruit and are produced globally. Commercial apple production in California has occurred for only a couple decades, yet California is one of country's 5 largest apple producing states, with orchards in many counties, although the highest concentration are in the aptly named "Apple Hill Region" in the Sierra foothills.[2] Apple trees bear fruit once a year, and the harvest time for popular varieties such as Fuji and Gala occurs in mid-fall. Apples are grown across the globe, with Southern Hemisphere producers such as Chile, South Africa and New Zealand[3] among the top 10 exporting nations by both weight and value. The harvest cycle for Southern Hemisphere producers is opposite that of the Northern Hemisphere. Thus, if a US consumer purchases fresh apples in late spring, apples sourced locally will have spent months in cold storage, whereas apples from New Zealand or Chile may have just been harvested.

We consider several scenarios for how a supermarket could source apples for a San Francisco store. Safeway has been selected for their market share and their emphasis on selling local produce. According to their website,[4] 30% of store produce is locally sourced. The definition of *local* can be contentious and the subject of discussion by researchers such as Darby et al. (2008). USDA guidelines allow food produced within the same state or within 400 miles to be labeled as "local." [5] Although apples are sold in many configurations, our standard measure for apples will be a plastic clamshell container containing 4 apples, such as the one pictured. This results in a volume of **0.0036** cubic meters and an average weight of **1 kilogram**. First, we use

[1] Milà i Canals L, SJ Cowell, S Sim, L Basson (2007) Comparing Domestic verses Imported Apples: A Focus On Energy Use, *Environmental Science and Pollution Research* **14**(5): 338-344.

[2] For more information visit the following website: http://www.allaboutapples.com/orchard/ca.htm

[3] Based on database query at http://www.fas.usda.gov/psdonline/psdQuery.aspx See also: http://international-trade-leaders.suite101.com/article.cfm/top_ten_apple_countries

[4] Per http://www.safeway.com/IFL/Grocery/CSR-Locally-Grown

[5] Darby, K, MT Batte, S Ernst, B Roe (2008) Decomposing Local: A Conjoint Analysis of Locally Produced Foods, *American Journal of Agricultural Economics* **90**(2): 476-486

S. Cholette, Associate Professor of Decision Sciences, SF State University
Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino

CargoScope to estimate the energy and emissions associated with the transport and storage of apples. As CargoScope does not provide direct support for calculating energy used during agricultural production, we can reference academic literature for these figures.

Scenario 1: Apples Grown and Purchased within Season in California

First, we consider that apples are sourced within California during the harvest season. Thus only minimal storage time is required, resulting in no yield loss. Although in this and all following scenarios we describe the supply chain from a *push* viewpoint, with flows downstream (the retail store in San Francisco, in all cases), when we model in CargoScope, we consider the complementary, upstream view.

1) Apples produced by an El Dorado orchard in the Sierra foothills are transported by a fully utilized, gasoline powered large pickup truck from the farm to the Safeway distribution center (DC) in Tracy 150 km away, for storage and sorting to some of the 260 stores serviced by this DC.[6] The pickup truck returns to the farm empty (0% backhaul).
2) The apples are stored in the distribution center for 2 weeks, with cooling. *We assume 100% utilization of a unit with 10 cu meter capacity for all cooled storage.*
3) Apples are then sent 100 km to a retail store in San Francisco, in a cooled midsized truck with 100% utilization, no backhaul. Although utilization figures are hard to verify and likely to vary, for consistency we will assume 100% utilization for all commercial trips and, for any trucking, 0% backhaul for this and all other scenarios. *It should be noted that Cargoscope automatically assumes shared transport modes (air, rail and ship) have 100% utilization and backhaul.*
4) The apples are assumed to be sold after a week, with similar cooling as per the DC.

When we model this supply chain in CargoScope, we consider the *pull* view. Our root is the San Francisco retail store, which gets apples from the DC at Tracy, in turn supplied by the farm located in El Dorado. This is shown in the following figure:

Consumers at the San Francisco store may drive, take public transit, or even walk or bike to the store. Furthermore, those driving may be shopping for the week on the way home from work or taking a dedicated trip to purchase the apples. Thus the estimating energy associated with transport after the

[6] The Tracy DC is one of Safeway's largest, servicing 260 stores, including those in the Bay Area, per http://eastbay.bizjournals.com/eastbay/stories/2003/06/30/daily10.html While DCs are not always easy to locate, it is often possible find them via job postings, such as http://shop.safeway.com/corporate/safeway/careers/store_locator.asp

S. Cholette, Associate Professor of Decision Sciences, SF State University
Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino

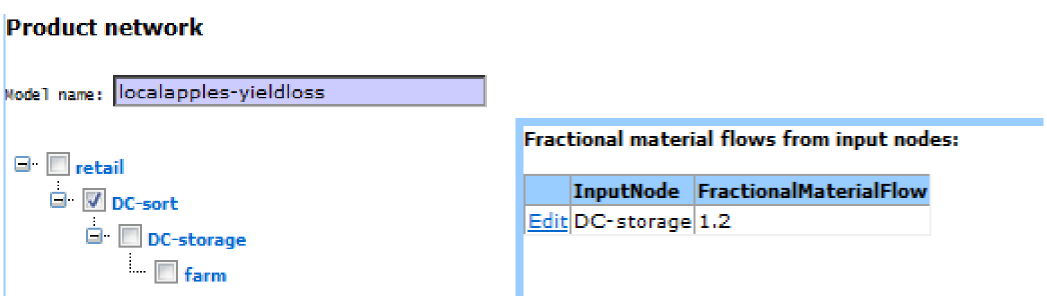
apples have been purchased is difficult. But given our limited frame, CargoScope calculates the energy consumed during storage and transport is 3.4 MJ/kg, resulting in .233 CO_2e/kg emitted. The majority of the energy is expended during the trip from the farm to the DC.

NodeOrLink	Type	Mode	Time	Dist	Energy	Carbon
DC < > Farm	Transport	LargePickupTruck, Gasoline	0.09	150	2.7	0.187
Retail < > DC	Transport	MidsizeTruck, Diesel, Cooler	0.06	100	0.4	0.03
DC	Storage	Cooler, Electricity-US-Pacific	14	0	0.2	0.011
Retail	Storage	Cooler, Electricity-US-Pacific	7	0	0.1	0.006
TOTAL			21.15	250	3.4	0.233

<u>Scenario 2: Apples Grown and Purchased in California, with Long Term Storage</u>

Local apples that are sold out of season to San Francisco consumers are assumed to go through the following supply chain:

1) As with the first scenario, apples produced in El Dorado County are transported by pickup truck from the farm to the Safeway DC in Tracy, 150 km away, for storage. We assume that the apples are stored for six months (180 days) in the DC with the same cooling setup as before.
2) Milà i Canals et al. (2007) find that such long term storage often leads to significant yield losses in apples. We model this by dividing the DC into two nodes- one for storage and, one for sorting. At the DC-sorting node is closer to the end consumer, as shown below, to the left. The only characteristic we input for this node is found under "storage properties" where we specify a 1.2 fractional material flow from the DC-storage node, as shown below, to the right. This is effectively saying that it takes 1.2 kg of stored apples to produce 1kg of saleable apples, with the remainder culled due to spoilage.



3) After the six month storage and sorting the apples are then sent to the San Francisco Safeway, 100 km away. As in the first scenario the midsized truck used will have cooling, 90% utilization, and no backhaul.
4) Again, as with the first scenario, the apples are assumed to be sold after a week, with similar cooling as per the DC.

CargoScope results for storage and transport are shown below, with 6.8 MJ/kg of energy used, resulting in .431kg CO_2e/kg. Note that cooled storage accounts for nearly half of the energy usage. Additionally,

S. Cholette, Associate Professor of Decision Sciences, SF State University
Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino

the higher energy usage and emissions associated with transportation from the farm to the DC are due to yield loss. That is, we need to transport 1.2 kg of apples for every saleable kilogram of apples.

NodeOrLink	Type	Mode	Time	Dist	Energy	Carbon
farm<>DC-storage	Transport	LargePickupTruck, Gasoline	0.09	150	3.24	0.224
DC-sort <> retail	Transport	MidsizeTruck, Diesel, Cooler	0.06	100	0.4	0.03
retail	Storage	Cooler, Electricity-US-Pacific	7	0	0.1	0.006
DC-sort	Storage	None, Electricity	0	0	0	0
DC-storage	Storage	Cooler, Electricity-US-Pacific	180	0	3.04	0.172
TOTAL			187.15	250	6.78	0.431

<u>Scenario 3: Apples grown in New Zealand and imported to California in Season</u>

In this scenario, apples are harvested and immediately shipped to California, spending little time in storage, so no yield loss occurs.

1) Apples produced in the Nelson region of New Zealand[7] and are transported 30 km away to the Port of Nelson for export, by a large, gasoline powered pickup truck.
2) Apples are shipped from the Port of Nelson to the Port of Long Beach via small bulk carrier. The distance between the two ports is calculated[8] at 10,922 km, and cooling is assumed. *Although CargoScope appears to allow users to overwrite Utilization and Backhaul figures, these are kept at the defaults of 100% for all high-volume, shared transport modes (i.e. rail, air and ship). CargoScope also displays null values for the fuel efficiency and storage capacities, although that is clearly not the case in the underlying calculations*.
3) From Long Beach the apples are transported 560 km to the Safeway DC in Tracy, CA. Apples are transported using a heavy duty truck with cooling.
4) At the Tracy DC the apples are stored for 14 days with the same cooling profile as assumed previously.
5) Apples are transported 100 km to the same Safeway in San Francisco, where they are assumed to take a week on average before being sold to customers.

   CargoScope calculates that the transport and storage of these imported, in season apples takes 4.6 MJ/kg of energy, resulting in .34 CO_2e/kg of emissions. The most energy-intensive part is indeed the overseas journey, but this is comparable to the per kilo energy consumed in transporting California-grown apples by pickup truck 150 km to the DC. CargoScope calculates that transport and storage energy use from this scenario is less than that from Scenario 2, for long term storage of locally grown apples.

[7] A prominent apply growing area, per http://www.nzs.com/new-zealand-weather/nelson/

[8] Calculated as per http://www.daftlogic.com/projects-google-maps-distance-calculator.htm

Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino

NodeOrLink	Type	Mode	Time	Dist	Energy	Carbon
Retail <> DC	Transport	MidsizeTruck, Diesel, Cooler	0.06	100	0.4	0.03
Port of Long Beach <> DC	Transport	HeavydutyTruck, Diesel, Cooler	0.33	560	1	0.074
Port of Nelson <>Port of Long Beach	Transport	Ship-SmallBulkCarrier, BunkerFuel, Cooler	16.38	10922	2.36	0.183
NZ Farm <> Port of Nelson	Transport	LargePickupTruck, Gasoline	0.02	30	0.54	0.037
DC	Storage	Cooler, Electricity-US-Pacific	14	0	0.2	0.011
Retail	Storage	Cooler, Electricity-US-Pacific	7	0	0.1	0.006
TOTAL			37.79	11612	4.6	0.341

Scenario 4: Apples grown in New Zealand and imported to California with Long Term Storage

In this scenario, we are harvesting apples and immediately shipping them to California, where they will spend significant time in storage at the Safeway DC, resulting in yield loss. We modify the prior scenario by increasing the time at the DC to 180 days and, next, by including a sorting stage, similar to what was done for Scenario 2, where 1.2 kg of apples must come from storage to result in 1 kg of saleable apples, due to the 20% yield loss.

CargoScope results are shown below, with 8.23 MJ/kg of energy used during storage and transport, resulting in .56 kg CO_2e/kg. Note that this scenarios is the most energy and emission intensive of the four scenarios considered, with both long term cool storage and overseas shipping contributing most to the footprint.

NodeOrLink	Type	Mode	Time	Dist	Energy	Carbon
TracyDC-sort <> retail	Transport	MidsizeTruck, Diesel, Cooler	0.06	100	0.4	0.03
Port of LongBeach <> TracyDC-storage	Transport	HeavydutyTruck, Diesel, Cooler	0.33	560	1.2	0.089
Port of Nelson <> Port of LongBeach	Transport	Ship-SmallBulkCarrier, BunkerFuel, Cooler	16.38	10922	2.84	0.219
Nelson Farm <TO> Port of Nelson	Transport	LargePickupTruck, Gasoline	0.02	30	0.65	0.045
retail	Storage	Cooler, Electricity-US-Pacific	7	0	0.1	0.006
TracyDC-sort	Storage	None, Electricity	0	0	0	0
TracyDC-storage	Storage	Cooler, Electricity-US-Pacific	180	0	3.04	0.172
TOTAL			203.79	11612	8.23	0.56

Summarizing the Scenarios and Considering Production

As noted, none of these scenarios consider the energy associated with production, and we must turn to another source. While they do not directly consider emissions, Milà i Canals et al. (2007) estimate the energy spent on producing apples ranges from 0.4 to 2.0 MJ/kg in Europe and most Southern

Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino

Hemisphere countries. While the US is not listed, we assume California apple production has a similar energy profile, and we use the midpoint of 1.2 MJ/kg. In reality, such energy usage is likely to vary between producers based on factors such as irrigation usage and harvesting techniques. This source also reports that New Zealand has favorable climate and soil conditions to grow apples, and hence, the energy spent to produce a kilogram of apples is estimate to range between 0.4 and 0.7MJ/kg (average = 0.55 MJ/kg), lower than other apple producing regions on average. In performing these scenario comparisons, as shown in the table below, we also account for the 20% yield loss assumed for long term storage; we need to grow 1.2 kg of apples for every 1 kilo of saleable out-of-season apples.

Comparing the Energy Intensity of Scenarios:

MJoules required to Produce, Transport and Store 1 Kilogram of Saleable Apples

	Description	Production	Transport	Storage	Total
Scenario1	local apples in season	1.2	3.1	0.3	4.6
Scenario2	local apples in long term storage	1.44	3.64	3.14	8.22
Scenario3	imported apples in season	0.55	4.3	0.3	5.15
Scenario4	imported apples in long term storage	0.66	5.09	3.14	8.89

S. Cholette, Associate Professor of Decision Sciences, SF State University
Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino

Questions

1. What factors contribute most to energy usage for apples? Does distance from production source appear to be the dominant factor?

2. Next consider how the energy and emissions associated with storage and transport would change for Scenario 4 if the apples were placed in long term storage in a cooled facility in Nelson rather than in Tracy. We will assume a warehouse is located 30 km away from the orchards from the Port. While CargoScope does not have New Zealand's electricity profile, it will have a fair amount of hydropower and we thus assume a similar mix as Canada's. Apples will still be transported to the warehouse by pickup truck, but then they get to the port, 10 km away, via a cooled midsized truck at 100% utilization, no backhaul, and these apples will then be sent to the US, with the remainder of the logistics profile then resembling Scenario 3. Place these changes in context.

3. What would happen to the energy and emissions profile of the New Zealand apples if they are flown from an airport near the Port of Nelson to LAX? (You may ignore the minor model inaccuracies that occur because airports and ports are not located in the exact same place), Despite the increased expense and energy usage, why might companies opt to use air-freight instead of shipping by sea?

4. Milà i Canals et al. (2007) estimate the energy associated with primary apple production for countries other than New Zealand ranges from as low as .4MJ/kg to as high as 2.0 MJ/kg. How do findings change if we assume different values within the range? Place these changes in the broader context of the analysis.

Points for Further Consideration

A. What does "local" mean to you? Would you be more inclined to purchase local produce if you knew it was grown within 50 or 100 miles, as opposed to the USDA's definition of 400 miles?

B. Outside of any energy usage and emissions concerns, what are some advantages of buying local produce over that from more distant sources?

C. When is the purchase of imported or more distantly sourced food items justified or even potentially more appropriate than local sourcing?

D. Unlike CargoScope, Milà i Canals et al. (2007) report energy usage only, not carbon emissions. Can we approximate the total carbon emitted for each of the scenarios? When are energy usage and emissions more likely to be decoupled?

E. Researchers have often ignored yield losses associated with long term storage. If we could perfectly preserve the apples for long term storage at the DC, show how the analysis would change for Scenario 2. Likewise, consider the extensive loss that often occurs with food waste at the consumer and retail level, where a substantial amount of the food grown, stored and transported ends up as waste Without using CargoScope, what is the impact to the carbon footprint of apples if half of the apples end up as waste at either the retail store or in the consumer's home?

Development of these materials made possible by a grant from the Leonard Transportation Center at CSU San Bernardino