

Available online at [www.fooddynamics.org](http://www.fooddynamics.org)

INTERNATIONAL  
JOURNAL ON  
FOOD SYSTEM  
DYNAMICS

Int. J. Food System Dynamics 3 (1), 2012, 74-81

---

## Farm-to-Fork: A Proposed Revision of the Classical Food Miles Concept

Alfred Wong<sup>1</sup> and Alan Hallsworth<sup>2</sup>

<sup>1</sup>*Friends of Aboriginal Health, Canada*  
<sup>2</sup>*University of Portsmouth, UK*

*taiping@aboriginalhealth.net, a\_hallsworth@btinternet.com*

Received May 2012, accepted September 2012, available online November 2012

---

### ABSTRACT

The “Food Miles” concept was introduced in the UK nearly two decades ago in order to highlight the emissions of CO<sub>2</sub> that arise during the transportation of food grown in distant locations. The concept has subsequently energized urban citizens to re-consider the on-purpose purchase of locally grown foods. The important contribution of CO<sub>2</sub> emitted in heated greenhouse operations has heretofore been routinely omitted from the “Food Miles” accounting protocol. In the analysis of tomato supply to Vancouver, the CO<sub>2</sub> emission was estimated to be about 7 times higher for tomatoes grown in local greenhouses than in local open fields.

*Keywords: carbon dioxide, emission, food supply, tomato, Vancouver*

---

### 1 Introduction

In recent decades, the inherent seasonality of foodstuffs that can be grown locally has eroded. Powerful food retailers who, in most Western economies, effectively form an oligopoly that takes the majority of food sales, have long held the capacity to source globally. Accordingly, urban citizens have become accustomed to finding a year-round supply of fresh foods such as tomatoes. We particularly focus on seasonal foodstuffs that can be grown locally – using tomatoes as our example – since products such as bananas have always had to be sourced at a distance and must be transported over great distances. The tomato problem, is, we argue, a sub-set of the general Food Miles debate since long-distance transportation is not the only means of sourcing. We note that greenhouse-grown tomatoes provide an alternative source. Ongoing debates over alleged deficiencies of the “food miles” concept are still largely focused on the precision and completeness of accounting CO<sub>2</sub> emitted in the road transportation of food to various markets (Coley et al., 2008; Coley et al., 2011). Amani and Schiefer (2011) have provided a summary of the protocols available for the calculation of carbon footprint of the food sector. It is interesting to note that there are little or no published data on CO<sub>2</sub> emission in the operation of greenhouses which are specifically heated by the combustion of fossil fuels. Probably for commercial reasons, the Dutch appear to have been somewhat vague in their reporting of actual CO<sub>2</sub> emitted by their highly-intensive greenhouse horticultural operations (van der Velden and Smit, 2009; van der Velden and Smit, 2010). Co-generation of steam and power was cited as the means to justify the high usage of fossil fuel (viz., natural gas) in Dutch greenhouse operations.

The environmental impact of various types of greenhouse cropping, as well as greenhouse cropping versus open-field cultivation, in a fixed single location such as southern Italy (Cellura et al., 2012), southern Spain (Romero Gámez et al., 2012) and eastern Spain (Martínez Blanco et al., 2011) have been reported recently. Torrellas et al. (2012) have compared, among other things, the environmental impact of tomato cropping in plastic greenhouses in Spain and glass greenhouses in the Netherlands. But there has essentially been no integration such information into the overall estimate of “food miles” in the delivery

of produce on a farm-to-fork basis. In particular, there has been no direct comparison of CO<sub>2</sub> emissions of local produce (e.g., short transportation distance + heated greenhouse cropping) and distant produce (e.g., long transportation distance + open field cultivation) delivered to northern-latitude markets. This matter is relevant because, in related work on Portsmouth (England), Hallsworth and Wong (2012) have demonstrated that tomatoes for sale out of season are imported routinely from Almería (Spain) but also the Netherlands. Because tomato is a tropical solanaceous fruit crop, adequate temperature and incident light conditions are needed for year round cultivation in these northern temperate-zone regions. Essentially, if tomatoes are not growing out of doors in England, they will not be growing out of doors in the Netherlands either. Dutch-supplied tomatoes to England must be coming from greenhouses. Hallsworth and Wong (2012) have shown the avoidable CO<sub>2</sub> emission as manifested by large amount of fossil-fuel energy used in greenhouse heating to be substantially larger than that incurred from the road transportation of tomatoes grown in open fields in southeastern Spain to Portsmouth (50.5° N, 1.5° W). The carbon footprint for greenhouse-grown tomatoes was found to be nearly 10 times larger than that for regional field-grown tomatoes, on the same delivered basis.

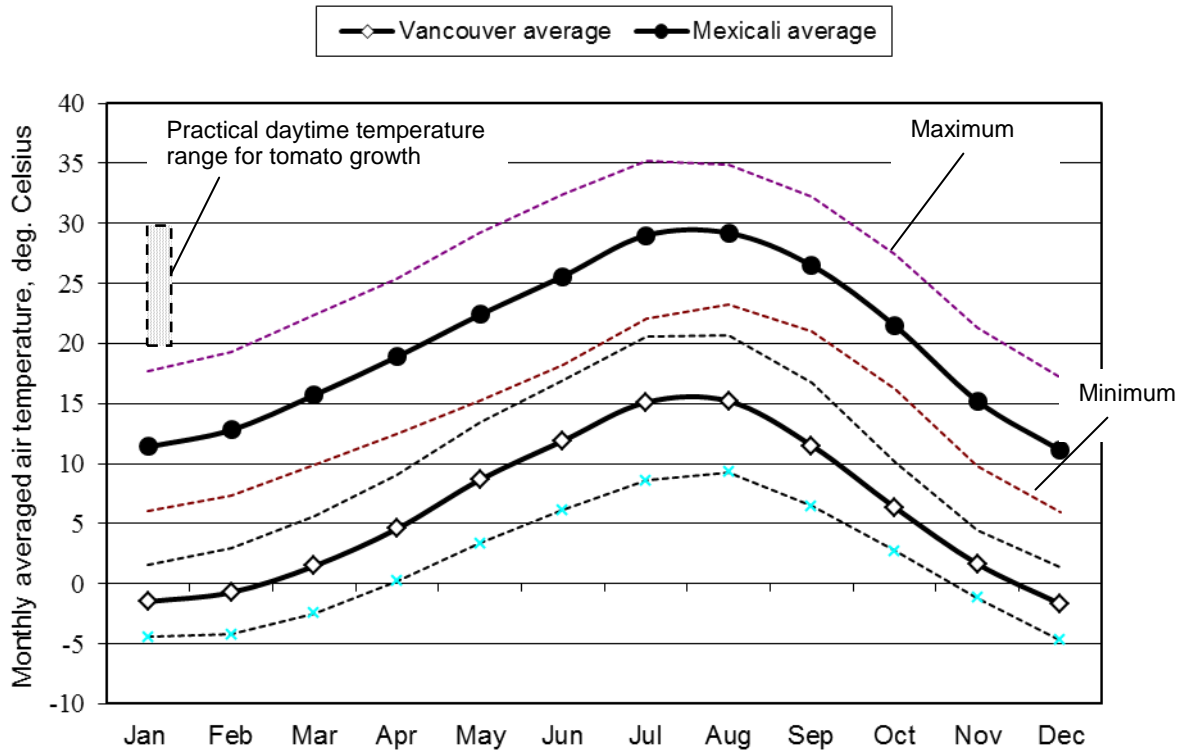
The purpose of the present study was to assess the modality of supply of fresh produce to Vancouver (49.3° N, 123.1° W), a typical northern latitude medium-size metropolis in west coast North America. Verification of the principal findings of the aforementioned Portsmouth study (Hallsworth and Wong, 2012) was achievable as the access to fresh vegetables in Portsmouth (UK) and in Vancouver (Canada) is substantially similar.

## 2 Methods

The methodology deployed was the same as that used previously for the Portsmouth study (Hallsworth and Wong, 2012). In essence, reference CO<sub>2</sub> emission data published by various government agencies of Canada (e.g., Environment Canada and Natural Resources Canada), the UK (e.g., Department for Environment, Food and Rural Affairs) and the USA (e.g., California Department of Transportation and US Environmental Protection Agency) were used routinely for the estimation of the CO<sub>2</sub> emission in the combustion of basic fossil fuels for heating, and for the surface transportation of goods. It may be noted that these published figures are *average* CO<sub>2</sub> emissions based on *average* driving or operating conditions. Although actual emissions may vary significantly in practice, it is the order of magnitude of CO<sub>2</sub>-emission that is being sought.

## 3 The tomato supply model

The supply of tomatoes provides a good illustration of the comparative fresh-vegetable purchase models available in Portsmouth and Vancouver. As demonstrated by Figure 1, the temperature profile of Vancouver is clearly very marginal for the field production of tomatoes. However, some local farmers are engaging in field cropping of tomatoes, particularly the Fraser Valley located 50 to 100 km east of Vancouver. The ambient temperature of the Fraser Valley is customarily more than 5 degrees Celsius higher during the summer months. Conversely, in Mexicali, the field cropping of tomatoes is typically suspended during the extremely hot summer months. Because field-grown tomatoes are not available year-round in the Vancouver region (nor in the Portsmouth area), greenhouses have routinely filled the gap in tomato supply. For latitudinal climate reasons, the demand for heating energy in Vancouver greenhouses can be expected to be similar to that in greenhouses located in the Netherlands and southern England. Natural gas is the principal source of fuel used in Vancouver greenhouses.



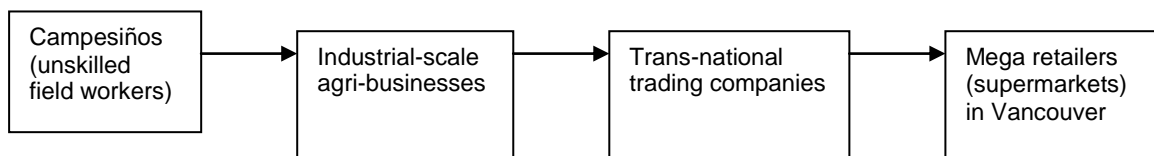
Source: ASDC, 2012

Figure 1. Monthly averaged (22 years) air temperature at 10-m above the surface of the Earth

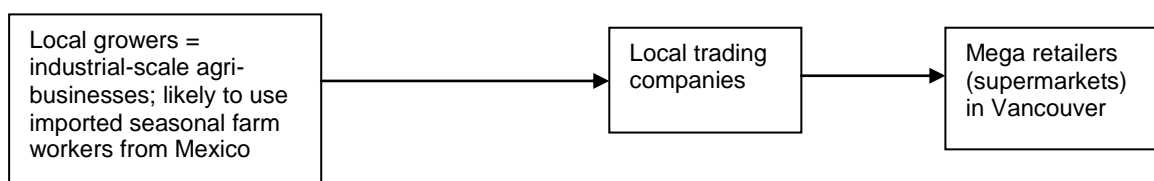
Figure 2 shows the three tomato-supply models for Vancouver constructed for the analysis of avoidable CO<sub>2</sub> emissions. Fresh, field-grown, tomatoes sold in supermarkets in Vancouver are routinely imported from farms in northwestern Mexico (including the states of Baja California, Sonora and Sinaloa) and the Central Valley of California. See Figure 3. The travel distance of lorry transport from Mexicali (located at the Mexico-USA border) to Vancouver is about 2,400 km. During the summer months, local field-grown tomatoes are also widely available in local supermarkets, as well as in the weekly farmers' markets at several locations in Vancouver.

There are several industrial-scale greenhouse operations located immediately south of Vancouver; they supply tomatoes year round to supermarkets and other smaller retail grocery outlets. Interestingly, the retail pricing of those tomatoes sold by local farmers directly in local farmers' market in the summer is competitive against ones imported from Mexico by super-markets. For example, the local retail price of tomatoes sold everywhere was C\$3.29 per kg, during July, 2011. This latter fact draws attention to the related topic of the power of large food retail oligopolies to dictate local food prices.

Model A – Buy field-grown Mexican imports from mega retailers (syn., supermarkets)



Model B – Buy local greenhouse-grown within 160 km of Vancouver from mega-retailers



Model C – Buy direct from field-grown producers located within 160 km of Vancouver

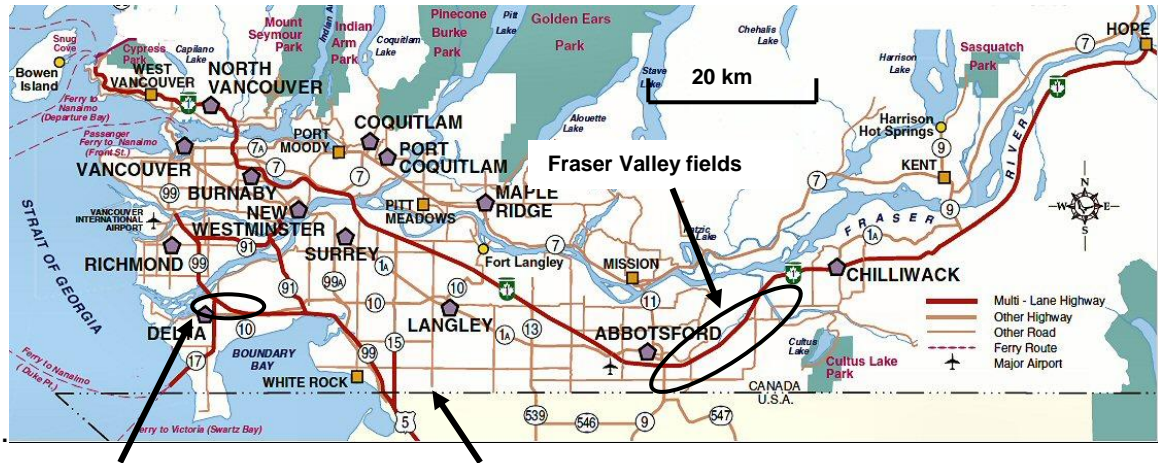
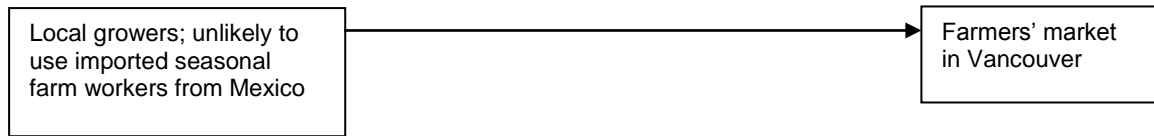


Figure 2. Retail purchasing models for tomatoes in Vancouver

Delta commercial greenhouses

International border

Adapted from BC Ministry of Tourism map

Note the high density of urban development and close proximity of mountains and the sea in this southwestern corner of mainland British Columbia.

Mexicali (Mexico) fields to Vancouver (Canada) road distance ~2,400 km.



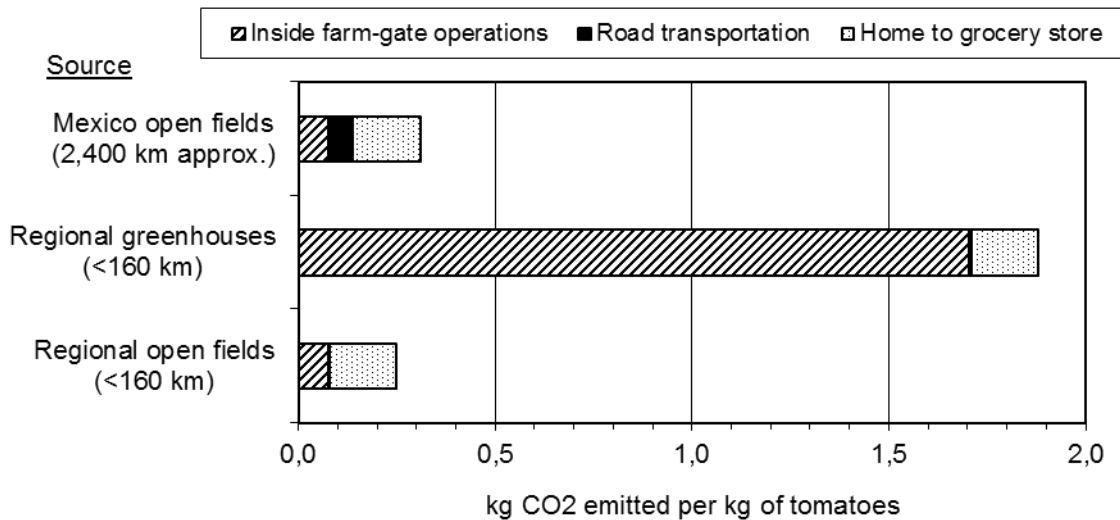
A substantial amount of the field-grown tomatoes available in Vancouver also originates in the Central Valley of California

Adapted from <<http://www.brennemann-deskart.de>> map

Figure 3. Geographical locations of the 3 sources of tomatoes

#### 4 Carbon footprint

In the supply of tomatoes to Vancouver, greenhouse-grown tomatoes were estimated to emit the highest amount of avoidable CO<sub>2</sub>. This arises from the use of natural gas for heating, especially through the off-season. Figure 4 shows the difference to be a factor of about 7 times greater. Accordingly, the total carbon footprint for Mexican field grown tomatoes was notably lower than that for local greenhouse-grown tomatoes, even though the Mexican tomatoes had to be transported (by trucks) approximately 2,400 km to Vancouver. Essentially, the much smaller footprint derived from lower local transport costs from nearby greenhouses is more than offset by the huge CO<sub>2</sub> emissions from keeping them heated.



Notes:

1. The CO<sub>2</sub> emission data for the “inside the farm gate” were based those cited by Hallsworth and Wong (2012).
2. The CO<sub>2</sub> emitted for the “home to grocery store” travel was based on the calculations given previously by Hallsworth and Wong (2012). A small gasoline-powered Car (KIA Rio; 2011 UK model) was assumed for the 1-km travel return trip from home to the grocery store for the single purpose of purchasing 1 kg of tomatoes.

Figure 4. Avoidable CO<sub>2</sub> emission for 3 different tomato-supply models for Vancouver

Details of the calculation of avoidable CO<sub>2</sub> emission for the 3 different tomato supply models are given in Table 1. Note that, further confirming the comparability of the two cities, the transportation distance for tomatoes from Mexicali to Vancouver is about the same as that from Almería to Portsmouth. The substantially lower CO<sub>2</sub> emission for the Vancouver case (0.06 kg CO<sub>2</sub> per kg tomatoes versus 0.61 kg CO<sub>2</sub> per kg tomatoes for Portsmouth case) resulted from a different method of calculation. Projected CO<sub>2</sub> emission from truck transport from Mexicali through west coast USA to Vancouver was based on the most efficient means of full-load non-stop motorway travel. In contrast, DEFRA (2011) data based on typical measured UK traffic conditions and loading capacity were used for the Portsmouth case. In other words, the data developed for the Portsmouth scenario (Hallsworth and Wong, 2012) were based on “realistic” European road transportation efficiencies. In the Vancouver case, the “idealized” road transportation efficiency was applied, for the lack of any measured data. The inside farm-gate CO<sub>2</sub> emission for greenhouse operations, mainly heating, for the Vancouver case was based on calculation of heat losses for a hypothetical greenhouse. The higher figures for UK and Dutch greenhouses for the Portsmouth case were based on published data of Albright and de Villiers (2008). In both cases of fresh-vegetable supply, the carbon footprint of greenhouse operation is an order of magnitude higher than that of road transportation.

There is no doubt that purchasing fresh vegetables which are field-grown many thousand kilometres distant would have a higher CO<sub>2</sub> emission impact than buying those which are field-grown locally. However, the avoidable CO<sub>2</sub> emitted per kg of tomatoes delivered would be substantially higher for tomatoes grown in heated commercial greenhouses, even if the greenhouses were located ‘next door to the consumer’. The notable exception is the case in which the greenhouse is heated with waste heat generated from an existing power and/or heat generation facility built for other purposes. Such circumstances are generally very rare in both North America and Europe. Because of short summer months, passive solar-heated greenhouses are not practicable year round in the Vancouver region. It may

be noted that in Mexicali, passive greenhouse technology is practiced to provide protection from certain crop pests, and to extend the growing season into the cooler winter months (See Figure 1). In the solar heating approach, there would be no CO<sub>2</sub> generated from the burning of fossil fuels to aid the photosynthetic process.

Given the fact that CO<sub>2</sub> emissions are found to be greater by a factor of seven when CO<sub>2</sub> emissions from greenhouse heating are factored in suggests that not all emissions are currently being accounted for if one sticks rigidly to the classic food miles concept. An extension of that original “food miles” concept is urgently needed in order to take into account the disproportionately large CO<sub>2</sub> emissions contribution of greenhouse operations. If purchasers are to make fully informed purchasing decisions, they need to know not only how far food has travelled but how it was produced.

**Table 1.**  
Detailed calculations of avoidable CO<sub>2</sub> emission  
in the supply of tomatoes to Vancouver

Basis:

- 100 tonne-km per litre, diesel economy, estimation based on a) full-truck load, and b) long-distance non-stop driving under favourable conditions.
- 2.663 kg CO<sub>2</sub> per litre diesel (Environment Canada, 2011).
- 0.027 kg CO<sub>2</sub> per tonne-km. This figure is notably lower than the “0.127” value given for all heavy goods vehicles cited in Table 7e of the DEFRA (2011) Guidelines.

Model	Origin of tomatoes	Travel distance	Diesel fuel (c)	Electric lighting (d)	Natural gas heating (e)	Total
		km	kg CO <sub>2</sub> per kg produce			
A	Mexico open fields (a)	2,400	0.064	0	0	0.064
B	Regional greenhouses <160 km (b)	160	0.004	0	1.700	1.704
C	Regional open fields <160 km	160	0.004	0	0	0.004

Notes:

- (a) The road distance from Mexicali (Baja California, Mexico) to Vancouver is about 2,400 km. The field-cropping location in Mexico is assumed to be Mexicali municipio, alongside the USA border.
- (b) Tomato (Solanaceae) grows best in the temperature range of 25 to 28 degrees Celsius. A “12-hour on, 12-hour off” heating cycle is assumed to provide required diurnal temperature variation.
- (c) Typical diesel fuel economy: 100 tonne-km per litre which is equivalent approximately 41.6 kg CO<sub>2</sub> per tonne of goods as calculated from the 2020 US/Canada regulatory target of 1 kg CO<sub>2</sub> emission per km (CARB, 2005), for a 40-ft semi-trailer truck with a maximum gross on-road weight of 36,000 kg (Cal DOT, 2011). Compliance with all relevant California state laws is required as all trucks transit through California from Mexico to Vancouver. Reference emission data: 2.663 kg CO<sub>2</sub> per litre diesel fuel (Environment Canada, 2011).
- (d) Most of the electric power produced in British Columbia is generated by hydroelectric means. The CO<sub>2</sub> emission is assumed to be zero.
- (e) Natural gas emission factor: 56 kg CO<sub>2</sub> per GJ (NRCAN, 2011). Assuming a diurnal cycle (i.e., 12 hours on and 12 hours off) for heating of a greenhouse located in the Lower Mainland. The average greenhouse yield in Canada in 2003 was reported to be 49.4 kg tomatoes per m<sup>2</sup> per year (USDA, 2005). Using the 1,650-m<sup>2</sup> (floor space) all-glass greenhouse model developed previously for the North Baltic Greenhouse Project (Wong, 2010), the estimated CO<sub>2</sub> emission level is calculated to be about 1,700 kg CO<sub>2</sub> per tonne of tomatoes produced year round at a representative Vancouver greenhouse site.

## 5 Concluding remarks

If reduction of overall farm-to-fork CO<sub>2</sub> emissions is the key target then classical “Food Miles” studies that only look at transport costs would be inadequate whenever they omit to account for the very high carbon footprint that is associated with the heated greenhouse production of fresh vegetables. In the case of tomatoes, the difference in CO<sub>2</sub> emitted per kg of produce was estimated to be nearly 7 times greater between ‘local’ greenhouse cropping and field cropping at 2,400 km away. Adding in the effects of greenhouse heating broadens out the scope of inquiry – but it is possible to go further. Another wider



societal question is whether anyone really has a dire need to eat tomatoes in the off-season. Indeed, a common complaint, usually by those old enough to remember when much fresh produce was only available seasonally, is that out-of-season produce lacks authentic taste. Though this, too, is likely to be conflated with the power of retailers to demand the supply of food that 'looks good on the shelves' no matter how bland may be its taste. Substitution of tomatoes by other seasonal vegetables with comparable nutritional and culinary attributes could be practicable in the modern "western" diet. Alternatively, canned or sun-dried tomatoes could be a practical substitute during the off-seasons. Certainly in the last few years the argument that one should revert to eating what is in season is growing more strongly – often driven by so-called celebrity chefs who seek to revive local and regional foodstuffs. The significant opposing force to this initiative is the continuing promotion of 'year round availability of fresh produce' by the profits-driven commercial interests of large agri-food producers and distributors. To a certain extent, consumer demand appears to be manufactured, and is not of alimentary necessity.

## References

- Albright, L.D., de Villiers, D.S. (2008). Energy investments and CO<sub>2</sub> emissions for fresh produce imported into New York State compared to the same crops grown locally. Final Report prepared for the New York State Energy Research and Development Authority, Cornell University, Ithaca, (NY), USA.
- Amani, P., Schiefer, G. (2011). Data availability for carbon calculators in measuring GHG emissions produced by the food sector. *International Journal on Food System Dynamics*, **2**: 392-407.
- Atmospheric Science Data Centre – ASDC (2012). Surface meteorology and solar energy. National Aeronautics and Space Administration, Langley (VA), USA. Available at <http://eosweb.larc.nasa.gov> (Accessed February 12, 2012)
- California Air Resources Board – CARB (2005). NAFTA/Mexican Truck Emissions Overview (11/12/04 Rev. 01/21/05). Attachment B. Available at <http://www.arb.ca.gov/enf/hdvp/bip/naftamextrk.pdf> (Accessed November 6, 2011).
- California Department of Transportation - Cal DOT (2011). Truck Services: Weight Limitations. Available at <http://www.dot.ca.gov/hq/traffops/trucks/trucksize/weight.htm> (Accessed November 6, 2011)
- Cellura, M., Longo, S., and Mistretta, M. (2012). Life cycle assessment (LCA) of protected crops: an Italian case study. *Journal of Cleaner Production*, **28**: 56-62.
- Coley, D., Howard, M., and Winter, M. (2009). Food miles: Time for a re-think? *British Food Journal*, **113**: 919-934.
- Coley, D., Howard, M., and Winter, M. (2011). Local food, food miles and carbon emissions: A comparison of farm shop and mass distribution approaches. *Food Policy*, **34**: 150-155.
- Department for Environment, Food and Rural Affairs – DEFRA (2008). Ensuring the UK's food security in a changing world: a DEFRA discussion paper. Available at <http://www.ifr.ac.uk/waste/Reports/DEFRA-Ensuring-UK-Food-Security-in-a-changing-world-170708.pdf> (Accessed March 6, 2012).
- Department for Environment, Food and Rural Affairs – DEFRA (2011). 2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. UK Department for Environment, Food and Rural Affairs. Available at <http://archive.defra.gov.uk/environment/business/reporting/pdf/110819-guidelines-ghg-conversion-factors.pdf> (Accessed November 8, 2011).
- Environment Canada (2011). Fuel Combustion. Available at <http://www.ec.gc.ca/ges-ghg/> (accessed January 19, 2012).
- Hallsworth, A.G. and Wong, A. (2012). Magnitude of CO<sub>2</sub> emission in supply of tomatoes to Portsmouth, England. *World Transport Policy and Practice*, **18** (3): 13-24.
- Martínez Blanco, J., Muñoz, P., Antón, A., and Rieradevall, J. (2011). Assessment of tomato Mediterranean production in open-field and standard multi-tunnel greenhouse with compost or mineral fertilizers, from an agricultural and environmental standpoint. *Journal of Cleaner Production*, **19**: 985-997.
- Natural Resources Canada – NRCAN (2011). Business: Industrial, Appendix B – CO<sub>2</sub> Emission Factors. Available at <http://oee.nrcan.gc.ca/industrial/technical-info/benchmarking/csi/appendix-b.cfm?attr=24> (Accessed November 6, 2011).
- Romero Gámez, M., Suárez Rey, E.M., Antón, A., Castilla, N., and Soriano, T. (2012). Environmental impact of screenhouse and open-field cultivation using a life cycle analysis: the case study of green bean production. *Journal of Cleaner Production*, **28**: 63-69.

- Torrellas, M., Antón, A., Rujis, M., García Victoria, N, Stanghellini, C., and Ignacio Montero, J. (2012). Environmental and economic assessment of protected crops in four European scenarios. *Journal of Cleaner Production*, **28**: 45-55.
- US Department of Agriculture – USDA (2005). North American greenhouse tomatoes emerge as a major market force. *AmberWaves*, April, 2005. Available at <http://www.ers.usda.gov/Amberwaves/April05/Features/GreenhouseTomatoes.htm> (Accessed January 19, 2012).
- van der Velden, N.J.A., Smit, P.X. (2009). **Energiemonitor van de Nederlandse glastuinbouw 2008**. LEI Rapport / Werkveld Sectoren en bedrijven 2009-092. LEI Wageningen UR, Den Haag, Netherlands.
- van der Velden, N.J.A., Smit, P.X. (2011). **Energiemonitor van de Nederlandse glastuinbouw 2010**. LEI-rapport/Onderzoeksveld Sector & Ondernemerschap 2011-053. LEI, Wageningen UR, Den Haag, Netherlands.
- Wong, A. (2010). Food miles and localized vegetable production in the North Baltic region. Proc. International Conference on Agricultural Engineering - AgEng 2010, Clermont-Ferrand, France, September 6-8, 2010.