Bringing Food Home: a case study analysis of carbon emissions and energy use for transporting food in local food networks

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Abstract

The global food system contributes up to 30% of anthropogenic GHG emissions, nearly a quarter of which comes from transporting and distributing food. A number of reports have pointed to the increase in “food miles” as one factor contributing to the food system’s climate impact. The local food movement arose as a challenge to this trend and today eating locally is now popular among eco-conscious consumers. However, numerous studies argue that measuring food’s climate impact is not as simple as reducing “food miles”, and that local food networks are not necessarily more climate friendly due to their heavy reliance inefficient modes of transport. One such local food network (LFN) is community-supported agriculture (CSA). To test this theory, I conducted a case study of a CSA located outside Norway’s capital city of Oslo. I analyzed carbon emissions and energy use to transport food from the farm to shareholders’ homes. Results show that emissions and energy use for transportation are significantly higher than in other food supply networks, both local and mainstream. They are also higher than life-cycle carbon emissions of production and distribution of food items available through mainstream channels. Seen strictly from the perspective of emissions and energy use per kilogram of product resulting from transporting food, eating locally in this case does not offer a less carbon-intensive alternative to the mainstream food supply chain. A sensitivity analysis demonstrates that scaling up the driving patterns of the case to other LFNs will lead to a significant jump in emissions. It also demonstrates that if the CSA model expands geographically and scales up production it can lead to reduced emissions. I conclude by discussing these results in the context of other aspects of sustainability and the responsibility for society at large, not just actors in local food networks, to take action on climate change.

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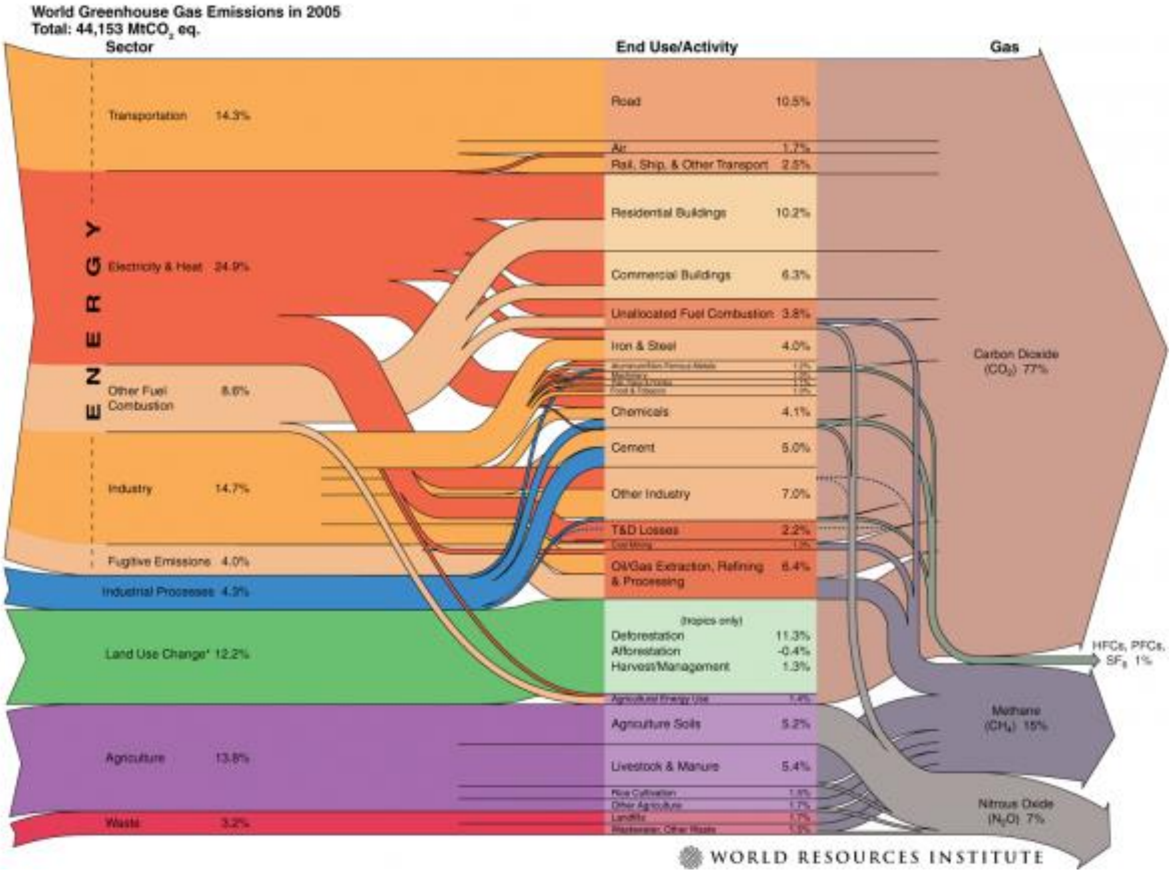
1 Introduction

1.1 Transportation and climate

It is estimated by some that the global food system is responsible for up to 30% of anthropogenic greenhouse gas emissions, when factoring in the contribution of land use change (Audsley 2009; Garnett 2011). At the household scale it is the single most important source, accounting for 20% of household emissions (Hertwich & Peters 2009). Agricultural activities alone account for 47% of methane (CH_4) and 58% of nitrous oxide (N_20) emissions globally. In terms of global warming potential (GWP), CH_4 and N_2O are 25 and 298 times more powerful, respectively, than CO_2 in a 100 year time horizon (IPCC 2007). From a lifecycle perspective, the bulk of emissions in the food system are associated with production, with the rest coming from land-use change, inputs (fuels, fertilizer and pesticide manufacture, and equipment), processing and packaging, transportation and distribution, preparation at home and in commercial kitchens, and decomposition of food waste (Audsley 2009; Hille 2012). Not only is the food system a major contributor to climate change, it is also considered to be extremely vulnerable to changes in climate and weather patterns, particularly in regions that are already suffering from drought and malnutrition (McIntyre 2009). Researchers and policy-makers alike are in agreement that action must be taken to reduce the food system's impact on the climate and better prepare it for climate change, but they are far from agreement on how to go about doing it.

One stage of the food supply chain that has received a lot of attention as a potential solution both in the popular media and in academia is transportation and distribution. In general, the transportation sector is considered to be the "largest end-use contributor to global warming" in most developed countries (Wakeland et al. 2012) and, as Figure 1.1 shows, the burning of fossil fuels is undoubtedly the greatest source of GHG emissions worldwide. In the food supply system, however, direct emissions from this stage make a relatively small contribution, accounting for only 12%-14% of the food system's total carbon footprint (Audsley 2009; Garnett 2011; Hille 2012; Wakeland 2012; Weber & Matthews 2008). While transportation's direct contribution to climate change may appear minor relative to other stages – and some argue that efforts to reduce emissions in the food system should be focused elsewhere (Weber and Matthews 2008) – there is still a growing movement to shorten the distance food travels to reach our plates. Aside from emissions, some argue, modern transportation networks enable scales and models of production that are inherently unsustainable and unjust, are dependent on a vast resource-intensive infrastructure, and come with great social, health, and economic costs (Garnett 2008; Marletto 2010; Pretty et al. 2005).

Figure 1.1: Distribution of global greenhouse gas emissions



Source: World Resources Institute: http://www.wri.org/chart/world-greenhouse-gas-emissions-2005

1.2 Food miles and local food

The term "food miles" was coined in the mid-1990s as a proxy for measuring food's sustainability. As the argument goes, the shorter the distance an item of food travels the more sustainable it is (Paxton 1994). Several well-publicized studies reported that for consumers living in developed countries, especially in the United States, the food on their plates often travels thousands of kilometers to get there (Pirog 2001). They correlated these long distances with more fuel consumption and emissions of greenhouse gas emissions, ultimately contributing to climate change. As a reaction, "local" and "short-travelled" food became a *cause célèbre* for the eco-conscious consumer and the concept of "local food networks" (LFNs) was born (DeLind 2011; Mariola 2008).[1] In 2007 "locavore", defined as someone

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[1] A note on terminology: The literature uses different terms to refer to various scales and structures of food networks. Mainstream food networks (MFNs) refer to dominant channels of production and distribution that supply food to supermarkets and the service sector worldwide. Local food networks (LFNs) are those in which food is produced and consumed within a limited geographical or political boundary, but they can be distributed

who restricts his or her diet to foods produced within a limited distance of where he or she lives, was selected as word of the year by the Oxford American Dictionary (DeLind 2011; DeWeerdt 2010). What exactly defines "local", however, is still up for debate. Some define it as food produced within a certain radius of where the consumer lives (hence the "100-mile diet"), others within bioregions or "foodsheds", and yet others within political boundaries such as counties, states, or even small nations (DeWeerdt 2010; Smith 2005). Regardless of the boundaries, proponents claim that eating "locally" is an alternative to an increasingly globalized food system. It is more climate-friendly, more ethical, and supports local economies because the food travels shorter distances, production practices are more transparent, and money goes directly to producers. In other words, it is as much a political act as it is an environmental one (DeLind 2011; Morgan 2010; Seyfang 2006).

So do local food networks meet these goals? The answer is *not necessarily*. Since the "food miles" debate began there has been no shortage of studies attempting to either confirm or disprove the merits of local food networks, particularly in relation to transport emissions. Mariola (2008) and Plassman & Edwards-Jones (2009), for example, argued that localizing the food system does little more than localize emissions, and may even lead to an overall increase in fossil fuel use. Others have claimed that local food systems are just as reliant on the global trade network and frequently dip in and out of the mainstream food supply system for procuring raw ingredients and for sales and marketing (Born & Purcell 2006; Ilbery & Maye 2005). Complicating matters is the fact that studies attempting to precisely calculate emissions and energy use among different food system models have come up with inconsistent and sometimes conflicting results. Van Hauwermeiren et al. (2007) concluded that in Belgium the mainstream food system is less carbon and energy intensive than local ones. Kulak (2010) found just the opposite when comparing mainstream food to that produced in community gardens around London and delivered by electric vehicle, and results for emissions in the mainstream system were very different from those calculated by Van Hauwermeiren et al. (2007). Thomsson and Wallgren (2005) calculated that transporting food locally in a region outside Stockholm was more efficient than transporting the same goods further away to the city center. A year later Wallgren (2006) concluded that there was no significant difference between carbon and energy intensities for transporting goods to a farmer's market in Stockholm (within 200 km of production) than for transportation in the

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and sold via mainstream channels. Alternative food networks (AFNs) are not necessarily local, but they operate outside the mainstream channels of production and distribution. Organic and fair-trade fall under this category. A combination of the latter two is referred to as local alternative food networks (LAFNs).

mainstream system (with goods travelling up to 24,000 km). Pirog et al. (2001) and Wakeland et al. (2012) both argued that coordinated regional networks, and not local or global, are in fact the most efficient. The list of studies is long and the conclusions equally varied.

Table 1.2: Comparison of energy and CO_2 intensities for various modes of transport

Transport mode and transport distance	MJ/kg	g CO2/kg
Short distance (400 km)		
Truck	0,75	54,66
Electric freight train	1,03	69,15
Continental (1500 km)		
Truck	2,80	204,98
Electric freight train	3,88	259,32
Freight aircraft	29,43	2149,20
Sea vessel	0,69	51,64
Intercontinental (6000 km)		
Freight aircraft	103,33	8509,68
Sea vessel	2,75	206,55

Based on Van Hauwermeiren, 2007

The reason why ‘food miles’ are an imprecise measure of sustainability is summed up by a report titled *The Validity of Food Miles as an Indicator of Sustainable Development* in which the authors list four factors that ultimately determine the impact of transport: 1) Transport mode; 2) transport efficiency; 3) differences in food production systems; and 4) wider economic and social costs and benefits (Smith et al. 2005). *Transport mode* refers to how the food is transported, i.e. by cargo ship, truck, local delivery, passenger vehicle, airplane, etc. Each of these modes has a particular rate of fuel consumption, emissions factor, and climate impact. Airplanes, for example, release emissions directly into the atmosphere whereas passenger vehicles are the largest source of local air pollution (Marletto and Silling 2010). *Transport efficiency* is very much related to the previous factor and refers to the load capacity of transport modes, which influences the ratio of CO_2 emissions per quantity of goods transported, and how quickly they can be loaded and unloaded. As Table 1.2 shows, cargo ships (which have a load capacity in the range of thousands of tons) make it possible to transport goods long distances relatively efficiently. Air and road transport are much less efficient because they are limited by how much they can carry relative to fuel consumption. As an example, air transport accounts for only 0,1% of travel kilometers in the UK, yet 11% of transport emissions (Smith et al. 2005). According to Hille et al. (2012), transporting goods from South America to Norway by cargo ship is less carbon intensive than transporting the same goods domestically in Norway.

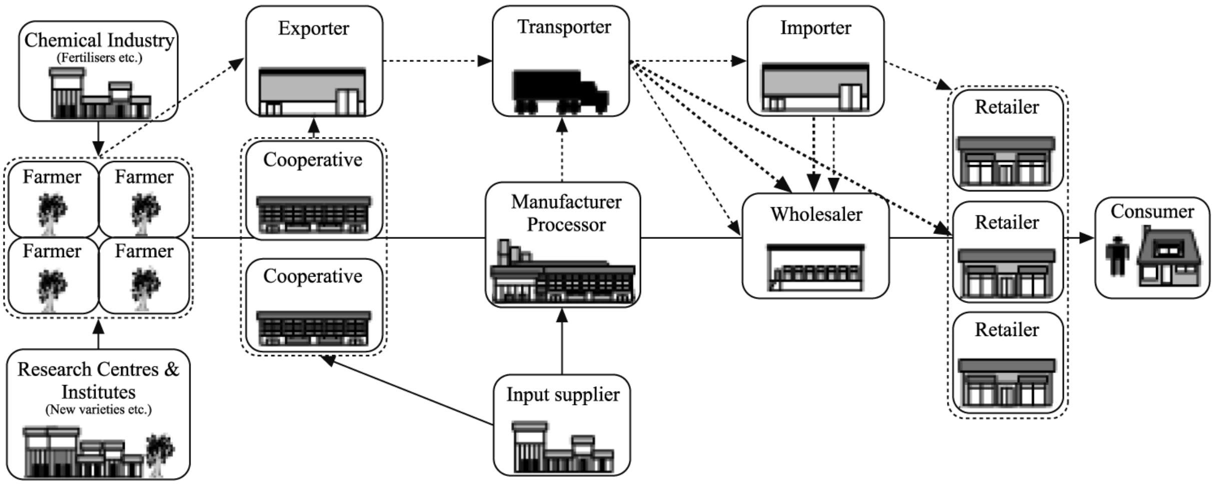
Third, *differences in food production systems* play a large role in determining the relative impacts of transportation when compared with total lifecycle emissions of goods. For products like red meat and hothouse tomatoes, which have high production emissions, transportation contributes relatively little. The same goes for highly processed or fresh food that requires a rapid and climate-controlled supply chain. One example is a study that compared lifecycle emissions of lamb meat from New Zealand imported into the UK versus meat produced domestically. They found that despite the long distances, lamb from New Zealand was in fact more climate friendly because production is much more efficient than in the UK where they have to heat barns in the winter and rely on hay and silage production (Saunders 2006). Other studies have shown similar results for imported tomatoes from Spain versus those grown in heated greenhouses (Carlsson-Kanyama 1998) and imported out-of-season apples in the UK versus domestic ones which are stored (Mila i Canals 2007; Rizet 2008). For most plant-based foods, on the other hand, emissions from transport can comprise the bulk of the product's carbon footprint. An extreme example of this would be fresh berries grown in South Africa and flown to European markets, as has become more common.

Finally, *wider economic and social costs and benefits* must also be considered when determining the impact of transportation. To use the example of Spanish tomatoes again, while they may be more climate friendly than those grown in Northern Europe because they can be grown without heating, they are grown in an area that suffers from water shortages and production is known to rely on undocumented immigrant workers with few rights (Garnett 2008). Production in many developing countries is not regulated, often displaces cultivation of traditional foods, and pays workers a fraction of what they require to meet their needs. On the other hand, some argue that export production is valuable for building up the economies of developing countries and that those workers have come to rely on the income, without which they would be worse off (Morgan 2010). At the same time, rural areas in developed countries are suffering from outmigration and their own economic slumps as domestic agricultural production is being supplanted by cheaper imports. Local food networks are seen as a potential solution to counteract these trends (Stagl 2002).

1.3 Choosing boundaries

Many studies assessing the food system employ the method of life-cycle assessment, or LCA, to determine the impact of transportation. LCA is a standardized tool used for calculating embodied lifetime environmental impacts of products and services by taking into account energy and resource inputs from “cradle to grave” (Garnett 2008; Schau & Fet 2008). Setting up an LCA study entails certain choices made by researchers: The choice of study boundary, choice of activities, and choice of metrics. Exactly where the food supply chain begins and where it ends is vague and easily disputable, and the source of much disagreement. According to Figure 1.3, for example, the food supply chain begins with the chemical industry, research centers and the farm, and ends with the consumer. It could also justifiably begin with the mines and oil wells from which the raw materials come and end at the landfill where most food waste ends up, adding significant emissions to the food system. In practice, most studies set boundaries from production up to the “farm gate”, or up to distribution to retailer. Once “upstream” and “downstream” boundaries are chosen, there is also a decision to make about which activities – and outcomes of these activities – to include or leave out. For example, when should the effects of land-use change be included and when should they not? Should the activities of actors in the food system be included, such as workers driving themselves to and from the supermarket? Finally, there is the choice of what metrics to use in measuring and expressing impacts of the food system. Impacts can be measured in terms of GHG emissions, energy use, embodied grams of oil, amount of land, etc. Each of these can shift the perceived environmental merits from one system or product to another without there being any changes in the study subject. Studies often employ different combinations of these three parameters, resulting in inconsistent conclusions and making it difficult to do side-by-side comparisons.

Figure 1.3: Food Supply Chain



Source: Matopoulos et al., 2007

One activity that is often left out of study boundaries – transporting food from the market to home – may also contribute as much if not more to food's carbon footprint than the entire journey from field to market, even for items that have travelled around the globe (Coley et al. 2009; Garnett 2011; Hille 2012; Marletto 2010; Mila i Canals 2007; Van Hauwermeiren et al. 2007; Wakeland 2012). It is also one of the least studied stages, meaning that there is a high degree of uncertainty about the extent of this stage's impact. In studying energy use in transportation for imported versus domestic apples and furniture, Browne et al. (2008) concluded that maritime transport for imported goods and the final consumer trip for all goods dominate energy consumption, though recommended that more studies need to be done on consumer driving habits because there is so much uncertainty about whether trips are dedicated or mulit-purpose. Coley (2009) found that 7,4 kilometers is the maximum distance for a consumer to drive to purchase food directly from the farm before it becomes more efficient to receive organic produce delivered via a box scheme, even if that produce has been through mainstream channels of packaging and distribution and travelled longer distances. Similarly, Wakeland et al. (2012) cite a study that analyzed wine distribution, and the least efficient mode by far was for consumers to drive to the winery to pick up the wine themselves. The most efficient was regional distribution through parcel delivery followed closely by national distribution via electric freight train. Pirog & Rassmussen (2008) analyzed the effect on emissions if shares from a community-supported agriculture operation were delivered to a central pick-up point by the farmer rather than customers driving to the farm and found that collective distribution was much more efficient, even if all the customers drove hybrid vehicles. Marletto and Silling (2010) compared emissions between national and regional tomato supply chains and found that despite the national scale being more efficient due to economies of scale, it tends to supply large, out-of-town supermarkets to which consumers have to drive. On the other hand, the regional scale supplies local markets located within walking and biking distance of consumers. In the final tally, the regional scale resulted in fewer emissions because it eliminated the need for consumers to drive. None of these studies provide an estimate for actual emissions or energy use of driving food from the market to home, but they clearly indicate that it is quite significant. If the final shopping trip is as significant as some studies claim then it could be that LFNs are in practice at least as carbon and energy intensive as mainstream food networks, even if they are successful in reducing "food miles".

1.4 Another kind of LFN: community-supported agriculture

It is safe to say that reducing "food miles" does not necessarily reduce GHG emissions from transport, but how do local food networks fare in terms of their social, political, and economic goals? There is some doubt that participation in such a network leads to any real changes in environmental awareness or consumer behavior. Mariola (2008) argued that local food networks are still enmeshed in market forces, are equally dependent on cheap labor, and are still embedded within a context of a consumerist society. To give an example, Wal-Mart – the world's largest retail chain and perhaps the epitome of what local food networks are reacting against – now offers "local food" in their stores (DeLind 2011; Ilbery & Maye 2005; Lockie 2009). And Wal-Mart is not the only multi-national food retailer to get on the local bandwagon. How does one differentiate "local food" distributed through this channel with that distributed through alternative channels? Without changes in the larger "socio-technical" context, Mariola (2008) concluded, "local" is not inherently better and buying "local" risks that consumers will be lulled into believing they are "doing their part" without creating any real changes to the underlying structures. As with the climate question, the answer is *not necessarily*.

One LFN model that may offer a true alternative is based upon an entirely different relationship between producer and consumer, and is gaining popularity in many European and North American countries: Community-supported agriculture (or CSA as it is often called). There are almost as many variations of the model as there are CSAs (in the US alone CSAs number in the thousands), but all are founded on the principles of shared risks and shared harvests (solidarity), dialog between producer and consumer (reciprocity), and transparent economy (fairness) (Terragni 2009; ØverlAndel 2011a). The CSA model first took form in post-WWII Japan and was further developed Germany and North America, from whence the model spread to other Western European countries and the rest of the world. Unlike traditional consumer arrangements, CSAs rely on members "buying" a share in the operation before the growing season begins. This guarantees the producer will have enough capital to purchase seeds and other equipment, at the same time reducing their risk of financial loss from failed harvests. In return "shareholders" (as members are often called) receive a portion of the harvest throughout the season, and the amount they get depends on the season and on the agreement they have made with the producer. In this way, the CSA model bypasses mainstream channels of production and distribution, i.e. supermarkets.

Most CSAs involve an arrangement between a single farm producing a variety of fruits and vegetables for a limited group of shareholders. Some have an expanded selection of products such as meat, milk, or eggs. There are also CSAs that make agreements with third parties to provide processed foods like bread, jams, and fibers. CSAs are not necessarily "local", but in practice they serve within a limited region. For those that are located far from population centers they often deliver shares to their members or to central pick-up locations. When they are located closer it is often the case that members are responsible for picking up their own. Shareholder involvement is another important aspect of CSAs, both on a practical level and as a forum for socializing. When possible, sharing the labor serves as a way for the farm to decrease costs and for shareholders to "get their hands dirty". Though not a rule, the vast majority of CSAs are certified organic or biodynamic, reflecting the strong environmental values of both shareholders and producers.

In Norway CSAs are called *andelslandbruk*, and the movement is relatively young. The first one, called ØverlAndel, was established in 2006 and as of 2013 there are eight CSAs in operation with several more in the planning phase (andelslandbruk.no). As with most CSAs worldwide, ØverlAndel places a high value on environmental practices. It is certified organic and has set for itself the goal of operating a farm with as small an ecological footprint as possible, with consideration for transportation and energy (ØverlAndel 2011a). In the organization's vision document it is stated that in their opinion all organic farms should be more proactive in addressing climate issues, including their own (ibid.). Shareholders in ØverlAndel also have a high degree of environmental and political awareness and are motivated by the desire to support organic agriculture, to consume organic products, to directly support producers, and value having a close connection to the source of their food (Rømo Grande 2009; Terragni 2009; ØverlAndel 2011b).

1.5 Assessing the significance of driving in a LFN: objective of the present research

The local food movement is a reaction to an increasingly globalized and industrialized food system that was made possible in large part because of modern transportation. Among others, reducing the food system's climate impact is an important motivation for actors in the movement. Ironically, it is possible that LFNs are just as dependent on transportation as mainstream networks and may in practice be contributing as much, if not more, GHG emissions because of their high dependence on passenger vehicles to transport small quantities of food. However, little is known about this final stage of distribution. As Hille et al. (2012) stated, "no environmental analyses of the logistics of alternative distribution systems such as farmer's markets or community supported agriculture… appear to have been carried out in Norway" (p. 55).

The purpose of this study is to analyze transport emissions from a single LFN in Norway – in this case a CSA – to determine how significant they are and whether they support or undermine the movement's stated goal of reducing the carbon footprint of the food system. Using ØverlAndel as a case study, I employ multiple methods to assess the extent of driving and resulting emissions and energy use relative to the quantity of food procured, beginning with a survey of shareholders to collect data on their driving and food collection habits. Next, I contextualize results from this case by comparing them to those of other transportation studies and to life-cycle emissions of goods available through other channels of production and distribution. I then conduct a sensitivity analysis to demonstrate how changes in shareholder behavior and vehicle choice can affect carbon emissions and energy use. Finally, I add the perspective of other important values of CSAs like raising awareness among consumers, recreation, connectivity, and supporting organic agriculture – all of which are important motivations for participants. I will discuss implications of the results in light of ØverlAndel's ecological principles, potential consequences of scaling up the CSA model, and possible courses of action they can take to reduce transportation emissions.

2 Material and Methods

2.1 Methodology

The current analysis uses case-study methodology as developed by Yin (2003) as a point of departure. Yin (2003) defines the case study as "an empirical inquiry that investigates contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (pg. 13). Within the umbrella of case-study design and methods there are numerous permutations. The approach used here can best be described as an *exploratory type-two single-case study*. It is *exploratory* because there has never been a study of alternative distribution systems in Norway (Hille et al. 2012), and very few in other contexts or settings. Therefore, it strives to answer "what" is happening in terms of vehicle use among members of a CSA and "how much" GHGs and energy consumption are resulting from transporting their food, without getting into answering questions of "why" or "how". It is a *single-case study* because the subject is a single CSA that is both unique and exceptional – a "critical case" in the words of Yin – for reasons that will be explained below. Finally, it is *type-two* because I employ multiple units of analysis, both qualitative and quantitative, in order to examine the issue from multiple perspectives. The results of this study will then be used to test the theory that local food supply networks in general are not reducing emissions as compared with the conventional food system against which they are reacting due to their reliance on driving.

2.2 The Study Case: ØverlAndel

ØverlAndel[2] was a natural choice for this study for several reasons. First, it was the first and still the largest CSA operating in Norway, making it an exceptional representation of this type of AFN. Second, due to its history and the organization's efforts to be transparent, it is the most documented CSA in Norway. Third, producing and supplying members with organic food that takes into consideration the environment and climate are explicitly stated among the organization's primary goals. In general, CSAs are unique among LFNs because they can potentially cover a greater portion of consumption needs and offer the most direct alternative to procuring food through the mainstream food system whereas other local producers tend to specialize in specialty products like cheese, bread, or meat products. There is also growing interest in this model and it will likely expand in the future.

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[2] The terms ØverlAndel and Øverland will be used throughout the article and they have different meanings. The former refers to the organization, whereas the latter refers to the physical location of the farm.

ØverlAndel was established in 2006 as a pilot project with the assistance of *Norges Vel* (or "The Royal Norwegian Society for Development", an independent development fund), *Oikos* (or "Organic Norway", an organic food advocacy organization), and *Grønn Hverdag* (or "Green Everyday", a sustainable lifestyle advocacy organization) as strategic and financial partners (founding member Jolien Perotti, pers. comm., 4th of April, 2012; Rømo Grande, 2009). It was founded on three principles: 1) shared harvest and shared risk; 2) dialog between producer and consumer; and 3) open and transparent economy. In addition, ØverlAndel's vision document states that the organization strives to operate a farm with as small an ecological footprint as possible with consideration for transportation, energy, and climate (ØverlAndel, 2011a). They also believe that organic farms in general should take more of a stand on climate issues and that organic standards in Norway do not go far enough to promote these efforts (Jolien Perotti, personal communication; ØverlAndel, 2011a). Participants are motivated primarily by the desire to promote organic agriculture, to have access to organic food, to have a direct connection to where their food is grown, and to be able to procure their food directly from the producer (ØverlAndel, 2011b).

Øverland is located in the municipality of Bærum, county of Akershus, about 16 kilometers west-northwest of the center of Norway's capital and largest city of Oslo (Figure 2.2). As of the 2012 season there were approximately 447 shareholders comprised of 330 adults, thirty-two between ages seven and fourteen, and eighty-five under the age of seven. Most members live in Bærum (about 100 members) and Oslo (about 90), with the rest in surrounding municipalities. The CSA leases 29 daa[3] of a much larger farm called Øverland Gård, which is owned by Norges Vel. Of this they have 14 daa in active production, growing a wide variety of produce such as fresh herbs, salad greens, tomatoes, beans and peas, potatoes and other root crops, squash, berries and fruit, and honey. In the future they hope to produce grapes, walnuts, and other perennial crops in addition to annuals. They are also considering animal husbandry. Since there is no fixed amount of produce per share, and members harvest their own, it is difficult to measure how much food is produced. Under current production they are unable to meet all the fruit and vegetable needs of members, although according to Perotti, that is a goal for the future. All harvesting operates on the honor system such that everyone uses their own judgment to harvest only what they think they can eat. According to Perotti, this system has worked well with few instances of abuse.

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[3] In Norway it is common to measure land area in decares, which is 1/10 of a hectare

As is common to most CSAs, ØverlAndel relies on its members for financial support, for planning and decision-making, and for a share of the labor. Three paid staff members are responsible for running the operation on a daily basis. They are hired as independent contractors by ØverlAndel and their incomes are paid by membership fees. Becoming a member in the CSA entails buying a share before each season. The fee for a share depends on the age of the shareholder. In the 2012 season adults over fourteen years of age paid NOK 2000 for a share, children between seven and fourteen paid NOK 1000, and children under seven were free. The season runs from May through October and members are responsible for harvesting their own produce. A weekly announcement is sent out via email during the season describing what is ready for harvest, where to find it, how to harvest it, and how much is available. Once the season is over, the CSA has storage for root and winter vegetables that members can collect from as long as supplies last.

In addition to harvesting their own produce, members are invited to participate in “Green Finger Days” (*Grønne Fingre Dager*) throughout the year. These are days organized around critical points during the season such as field preparation and planting in spring, weeding, and building projects. Participation is voluntary and members can contribute with labor or with support. Not only do these events serve the very practical purpose of getting work done, they are important for building and maintaining a sense of community among members and are a key to upholding the organization’s core values. These work parties, along with the fact that members harvest their own produce, help to keep production costs down and reduce the use of machinery.

Figure 2.2: Location of Øverland Gård and ØverlAndel

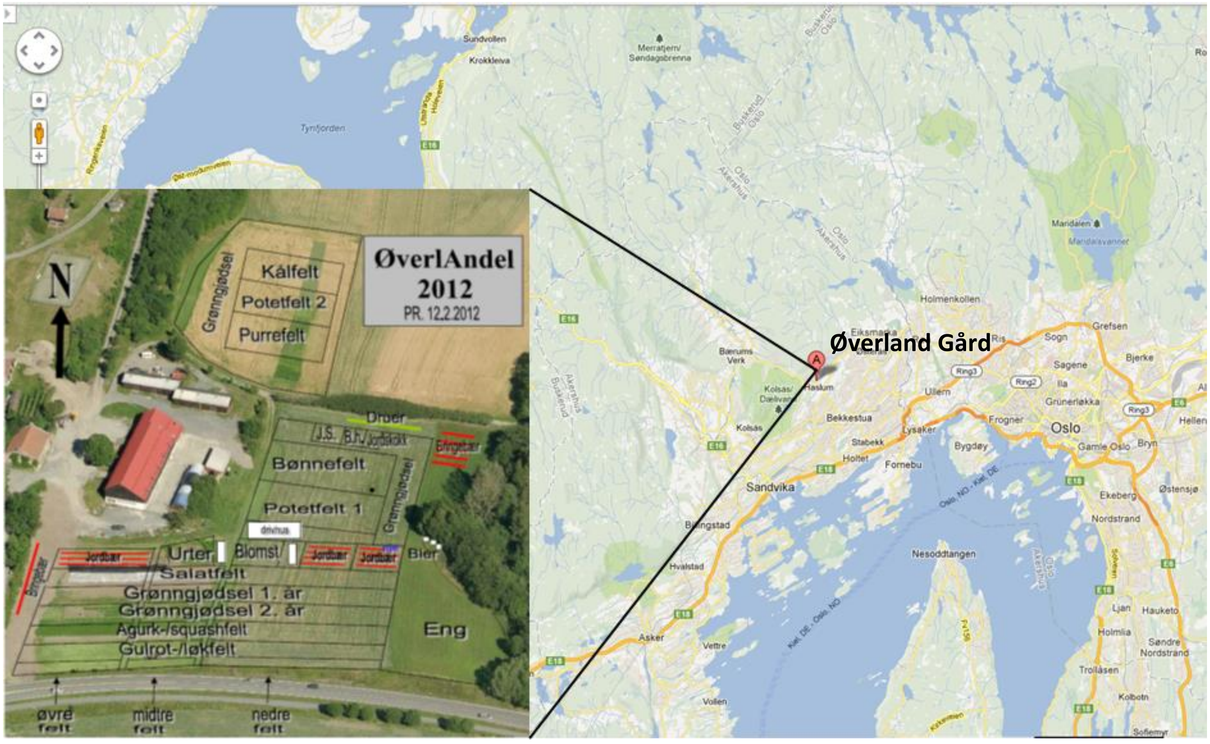


Photo: overlandel.no **Map:** Google Maps

2.3 Scope and Boundaries of Study

The scope and boundaries for this study are intentionally confined to encompass only direct CO_2 emissions and energy use resulting from transporting food from Øverland Gård to members' homes. The study does not account for non-CO_2 emissions resulting from vehicle use, or energy use and emissions from refining or transporting fuel, building or maintaining road infrastructure, manufacture of vehicles, etc. – all of which would add significantly to both the carbon footprint and energy use from transportation. I did ask whether trips to Øverland were combined with other purposes or if they were dedicated trips, but due to a low response rate for this question I was unable to factor results in calculations for emissions and energy use. However, some respondents individually noted that Øverland is on the way between work and home or close to where they work. In those cases, extra driving in order to pick up shares would be minimal and as such would result in a much smaller carbon footprint and energy expenditure associated with their food. These respondents were considered the same as those who took public transport, walked, or rode bicycles and were not included in calculations. It should also be kept in mind that calculations do not account for emissions from inputs, production, or processing food – stages of the food supply chain that typically make up the bulk of emissions in conventional food systems. However, due to the nature of this operation (organic, low-input fruit and vegetable production, relying on human power for much of the work, no processing or packaging involved, etc.), it is likely that methane emissions from production are relatively small, though the extent of N_20 emissions and loss of soil C are uncertain. Finally, the study does not account for consumer or post-consumer activities such as storage at home, preparation and cooking, and disposal.

2.4 Data Collection

2.4.1 Interview

A telephone interview with founding member and first manager Jolien Perotti was conducted on the 4th of April, 2012. It was an open interview format with questions focusing on the background and history of the organization, management practices, demographics of the members, and organizational values, particularly their stance on climate issues. In addition to her involvement with ØverlAndel, Jolien is also considered to be among those responsible for establishing the entire CSA movement in Norway. While not involved in day-to-day management of ØverlAndel any longer she is still an active member, and focuses more of her time and energy as a hired consultant for other CSAs in the planning and establishing phases. She is also a frequent speaker on the topic at conferences and seminars. I also communicated with current manager Anja Bruland in the course of the study to get additional information and for help with carrying out the survey.

2.4.2 Archive and Documentation

ØverlAndel operates a website (www.overlandel.no, in Norwegian) that is accessible to the general public. It serves multiple purposes, among others as a storehouse for documentation about the organization. Here it is possible to read about its history, founding principles and vision, harvest and activity calendars, and economy. Of particular interest to this study are the vision document (ØverlAndel, 2011a) and the annual evaluation survey (last completed following the 2011 season) in which members give feedback on a range of issues, from practical matters such as quality and quantity of the harvest, economy, organizational structure, and less practical matters such as motivations for participating (ØverlAndel, 2011b). Responses regarding motivations of members played an important role in the current study.

2.4.3 Survey

I collected data from members using the online survey site SurveyMonkey (www.surveymonkey.com). This study and the survey were presented by ØverlAndel manager Anja Bruland to members at a mid-winter meeting on the 30th of January, 2013.

Members were given an HTML link to the survey and requested to respond by the 8th of February. Paper copies were also made available for those who did not have internet access. Initially, the survey consisted of eight multiple-choice and open-ended questions written in Norwegian. The questions asked (translated into English) were: 1) “What type of transportation do you use to pick up produce at Øverland?”; 2) “If you use a car, what make, model, and year is it?; 3) What is the distance between where you live and Øverland?”; 4) “How many times in the course of the season do you pick up produce?”; 5) “If you use a car, do you usually drive alone or with other members? If with others how many are you in the vehicle?”; 6) “Approximately how many kilograms of produce do you collect each visit?”; 7) “Approximately what share of fruit and vegetable consumption does membership cover during the season?”; and 8) “What is the postcode where you live?”

Due to a low initial response rate and the desire to ask clarifying follow-up questions, a reminder to respond to the survey and an updated survey including two additional questions were sent out to members on the 18th of March. Those who had responded to the initial survey had the option of answering the two follow-up questions independently of the original survey, and those who had not participated in the first round were given a modified version of the original survey that included the two new questions. These follow-up questions were: 1) “If you drive to Øverland are the trips primarily a part of trips you would have made anyway for other purposes?” and 2) “If no, what percentage of the trips are carried out only for this purpose?” These follow-up questions give a clearer idea of how much driving is done purposely for picking up food. However, because the follow-up questions asking whether trips to Øverland are single or multi-purpose were asked separately from the original survey it is not possible to correlate these responses to other questions concerning driving habits or distance from the farm and therefore cannot be accounted for in the calculations.

For each respondent that marked that they use a car to pick up their share I looked up the fuel consumption ($L \cdot 100km^{-1}$) and emissions factor ($g \cdot CO_2\ km^{-1}$) based on the vehicle information given in the survey. I did not ask for detailed vehicle statistics in the survey such as engine size and fuel type (diesel vs. gasoline). Therefore, I had to estimate fuel consumption and CO_2 emissions using the website http://www.car-emissions.com/, which has a search engine for searching vehicles by brand, model, and model year. In some cases, the website gives specific statistics for individual vehicle models in a given year. In other cases, statistics are aggregated and averaged for all years that a model was produced. Since I did not ask whether respondents drive a diesel or gasoline vehicle I took the average fuel consumption and emissions factor for the two engine types. While possibly not precise enough for this particular study, the averages may give a more realistic picture of emissions as they are beyond the case studied.

2.5 Data Treatment

2.5.1 Emissions and energy consumption calculations

With SurveyMonkey I was able to export all the results into an Excel spreadsheet. In addition, I entered the fuel consumption and emissions data that I found from the internet search. Using these data, I based my calculations on methods used in several studies dealing specifically with emissions related to transportation within the food system. For calculating *transport carbon intensity* (CI) of the food I used Carlsson-Kanyama (1998), Thomsson and Wallgren (2005), Van Hauwermeiren et al. (2007), Coley et al. (2008), and Kulak (2010) for my methods. For calculating *energy use for transport* (E), *transportation energy intensity* (E_{int}) and *specific energy used* (E_{spec}) I used the formulæ from Thomsson and Wallgren (2005) and Wallgren (2006). I also divided results of the calculations by the number of passengers riding in the vehicle. Briefly, *carbon intensity* is a measure of the quantity of CO_2 emitted per quantity of a product, in this case g CO_2 per kg of produce from Øverland Gård. CI can be calculated to include emissions from the entire life-cycle of a product, or it can focus on discrete stages like transportation as was done in the current study. *Energy use for transport* expresses the amount of energy, in the form of megajoule, used to drive between home and Øverland. This value is a factor of distance driven and vehicle fuel consumption, and is independent of the quantity of food. *Transport energy intensity* is simply the previous value divided by the quantity of food transported. Finally, *Specific energy used* describes the amount of energy it takes to transport a certain amount of food a certain distance. Unlike E_{int}, this metric is independent of the distance travelled and is a function of the vehicle's fuel consumption and load.

I began by calculating g CO_2 emitted by vehicles per trip to Øverland. For this I used the formula,

$$EM*2d$$

where EM represents the emissions factor (g $CO_2 \cdot km^{-1}$) and d represents the distance from home to Øverland. I doubled d to account for the journey being a round trip. To calculate total emissions for the season I multiplied that result with the number of visits over the course of a season. To get total kilometers driven in a season I multiplied $2d$ with total number of visits. Since respondents had a choice between ranges of frequencies of visits (one time per week, once every other week, once per month, more than once per week, and less than once per month) I gave each choice a value. The season runs for approximately six months (May-October) so I assumed that there are 32 weeks within that period. Those who answered that they visit once per week were assigned a value of 32; every other week was given 18; once per month 6 visits; more than once per week given 42 visits; and less than once per week given 5 visits.

Next, I calculated total amount of produce picked up in a season by multiplying the number of visits times the amount of produce (in kilograms) the respondents estimated they pick up each visit. Again, the survey gave a choice of ranges. These were 1-4kg, 5-9kg, 10-14kg, and 15 or more. In order to calculate total amounts I averaged each range so that 1-4 became 2,5kg, 5-9 became 7kg, 10-14 became 12kg, and 15 remained the same. With these numbers I was able to calculate the CI of the produce (denoted as g $CO_2 \cdot kg^{-1}$). The final three calculations – *energy use for transport* (E)*, transport energy intensity* (E_{int}) and *specific energy used* (E_{spec}) – describe the total amount of energy used, in MJ, to make the trip from home to Øverland and back; the energy required to transport 1 kg of food; and the energy required to transport a specified amount of food a certain distance, respectively (Wallgren 2006). To find these values I first calculated for E, which is,

$$E=2d*f/100*C_{fuel}$$

where d is the distance from home to Øverland, f is fuel consumption of the vehicle (L/100km), and C_{fuel} is the energy content of fuel expressed as MJ/liter (this value is different for diesel and gasoline, and since I did not know which fuel the vehicles used I averaged the two values to get 33,36 MJ/liter). To calculate E_{int} I divided E by the quantity (q) of produce picked up per visit. Here is how this formula looks:

$$E_{int}=E \cdot q^{-1}$$

Finally, to calculate E_{spec}, I first divided f by two times the distance ($2d$), and then divided again by the amount of produce (q), to get a final value expressed as $MJ \cdot kg^{-1} \cdot km^{-1}$. The formula looks like this:

$$E_{spec}=(f/100 \cdot 2d^{-1}*C_{fuel}) \cdot q^{-1}$$

For all three values I also calculated on a per-passenger basis. To find this value I multiplied q by the number of passengers in the vehicle. Since I didn’t ask for the quantity that each passenger picks up I assumed that each one picks up the same amount as the respondent who is the driver.

2.5.2 Sensitivity Analysis of Scenarios

In addition to documenting statistics on current transportation and consumption patterns, I conducted a basic sensitivity analysis to demonstrate changes in emissions and energy results for hypothetical worst and best case driving scenarios. To do this, I substituted maximum and minimum values from respondents for the following parameters: emissions factor, fuel consumption, distance driven, quantity of food, frequency of visits, and number of passengers. With the resulting emissions and energy use values I then calculated percentage change from mean values in the survey. Though the sensitivity analysis is based on two extreme scenarios, it is useful for demonstrating the extent that changes in vehicle use for transporting food (or for any use) translate to actual emissions of CO_2.

3 Results and Analysis

3.1 Survey

When the initial survey was sent out, sixty-eight out of approximately 340 adult members of ØverlAndel responded by the deadline given. Following the reminder, which included links to the modified original survey and the two follow-up questions, an additional twelve respondents filled out the full survey for a total of eighty-one, and thirty-eight filled out only the follow-up questions (these were respondents who had filled out the original survey during the first round). Forty-eight surveys were completed in entirety and thirty-three surveys lack the two follow-up questions. This is within the range of response rates ØverlAndel receives when they send out their annual evaluation surveys (Anja Bruland, pers. comm., 28th January, 2013). A summary of the results can be seen in Table 3.1. Nearly three-quarters of respondents drive to Øverland to pick up their food and almost half make the trip once every two weeks during the season. Seventy percent of those who use a car drive alone and for nearly two-thirds of them trips to Øverland are not combined with other errands. Two-thirds of respondents pick up between one and four kilograms produce each visit and for forty percent of respondents their share covers between twenty-five and fifty percent of their fruit and vegetable consumption in season. Not shown in the table is the distribution of where respondents live. Thirty-seven respondents live in Bærum, thirty-four in Oslo, five in Asker, two each in Drammen and Nittedal, and one in Kongsberg. Twenty-five of the respondents from Bærum drive a car to get to Øverland, twenty-two from Oslo, and all respondents from the remaining municipalities with the exception of the one from Kongsberg, who takes public transportation. Results for vehicle statistics and distances between respondents' homes and Øverland are shown in Table 3.2.

Table 3.1: Summary of results from survey

Question	Responses	Percentage	Number
Type of transport used	**Car**	**73 %**	**59**
	Bicycle	17 %	14
	Public	7 %	6
	Walk	3 %	2
	Total	**100 %**	**81**
Frequency of visits to Øverland	Once per week	33 %	27
	Every two weeks	**46 %**	**37**
	Once per month	10 %	8
	> Once per week	4 %	3
	< Once per month	7 %	6
	Total	**100 %**	**81**
Drive alone or with others	**Alone**	**70 %**	**47**
	With others	30 %	20
	Total	**100 %**	**67**
Are trips multiple-purpose	Yes	36 %	18
	No	**64 %**	**32**
	Total	**100 %**	**50**
Percentage of dedicated trips to Øverland	0-25%	16 %	6
	25-50%	21 %	8
	50-75%	26 %	10
	75-100%	**37 %**	**14**
	Total	**100 %**	**38**
Kilograms produce picked up per visit	**1-4 kg**	**62 %**	**50**
	5-9 kg	33 %	27
	10-14 kg	4 %	3
	>15	1 %	1
	Total	**100 %**	**81**
Share of total produce consumption in season	<25%	25 %	20
	25-50%	**42 %**	**34**
	50-75%	21 %	17
	>75%	12 %	10
	Total	**100 %**	**81**

It is clear from the survey results that shareholders rely heavily on passenger vehicles for transporting themselves and their food to and from Øverland and make little use of alternative modes of transport. What's more, results indicate that the majority use their vehicles in an inefficient manner, either by not combining the trip with other errands or driving alone. A combined two-thirds cover 50% or less of their seasonal fruit and vegetable consumption through ØverlAndel, implying that they make additional trips to the supermarket to cover the rest of their consumption needs. Exactly how these behaviors translate into emissions and energy use will be demonstrated by the calculation results.

3.2 Carbon intensity and energy use from transportation for ØverlAndel

Table 3.2 shows baseline data and results from calculating carbon emissions, carbon intensity, energy use, energy intensity, and specific energy for transporting food from Øverland to respondents' homes. The results for most categories in the study (with the exception of E_{spec}) are positively skewed, suggesting either that values for most respondents fall below the average or that there are outliers at the higher end pulling up the mean. I color-coded the table to help keep track of the relationship between baseline data from individual respondents and corresponding results when applicable. This shows that while certain respondents repeatedly scored highest and lowest for different categories, there are some that appear only once. What's more, respondents that came out highest or lowest in one category are not necessarily the same for other categories. This demonstrates two things: 1) that there is a compounding effect of factors influencing carbon intensity and energy use; and 2) that it is difficult to assess who (or what) is most "climate friendly" because it depends in large part on the choice of metric (e.g., CI vs. energy use).

Illustrating these points are the following examples from selected respondents: The respondent with the most fuel efficient vehicle also lives only four kilometers from the farm and drives the least amount over the course of a season (48 km). As such, they emit the least amount of CO_2 and use the least energy over the course of the season. However, since that respondent does not pick up much produce each visit, the values for CI, E_{int}, and E_{spec} are slightly higher than the respondent who scored lowest in those categories (though still well below average) because those metrics are a function of quantity. The respondent who drives the shortest distance also picks up the most produce per season, helping to give them the lowest values for CI and E_{int}. The respondent with lowest value for the category of E_{spec} (without accounting for passengers) has the second most efficient vehicle, drives six kilometers, and picks up twelve kilograms per visit (or 216 kg total per season). Conversely, the respondent who had the highest value for E_{spec} has the second least fuel efficient vehicle, the highest emissions factor, drives five kilometers, and picks up only 2,5 kilograms per visit (45 kg total for the season). The respondent with the highest CI drives the most kilometers for the season and picks up only 2,5 kilograms each time. For the category of E_{int}, it is the respondent that drives the furthest per visit, has the least efficient vehicle, and picks up an average of seven kilograms per visit (126 kg for the season) that has the highest value.

Table 3.2: Maximum, minimum, mean, and median of baseline data and calculation results for CO_2 emissions and energy use from driving

	EM	***f***	***d***	***d total***	***q***	**gCO_2/ visit**	**gCO_2/ season**	**CI**	**CI/ pass**	**MJ/ visit**	**MJ/ season**	**E_{int}**	**E_{int}/ pass**	**E_{spec}**	**E_{spec}/ pass**
Max	310,6	11,8	42	2088	504	19034	342619	3076	3076	331	5952	47,24	34,05	1,35	1,35
Min	96,2	3,5	3	48[1]	15[1]	770	4618	89	89	9	56	1,03	1,03	0,11	0,05
Mean	179,1	6,2	11	483	96	3932	87865	1092	935	47	1038	12,64	10,68	0,63	0,55
Median	177,6	6,2	9	336	90	3252	58608	861	761	35	661	9,89	8,69	0,68	0,59

Values highlighted with the same color represent values from the same respondent.
EM – Emissions factor (g CO_2/km)
f – Fuel consumption of vehicle (L/100 km)
d – Distance between home and Øverland (km)
d total – Distance travelled in a season (May-October) between home and Øverland (km)
q – Quantity of produce picked up in a season (May –October) (kg)
CI – Carbon Intensity: the amount of CO_2 emitted from transportation per kilogram of food (g CO_2/kg)
E – Energy used for one round-trip journey to Øverland (MJ)
E_{int} – Transport energy intensity: amount of energy to transport 1kg food (MJ/kg)
E_{spec} – Specific energy used: amount of energy used to transport an amount of food (*q*) a certain distance (*d*) (MJ/kg-km)
[1] Two respondents drove 48 kilometers. One is highlighted in green. The other shares the value highlighted in dark blue.

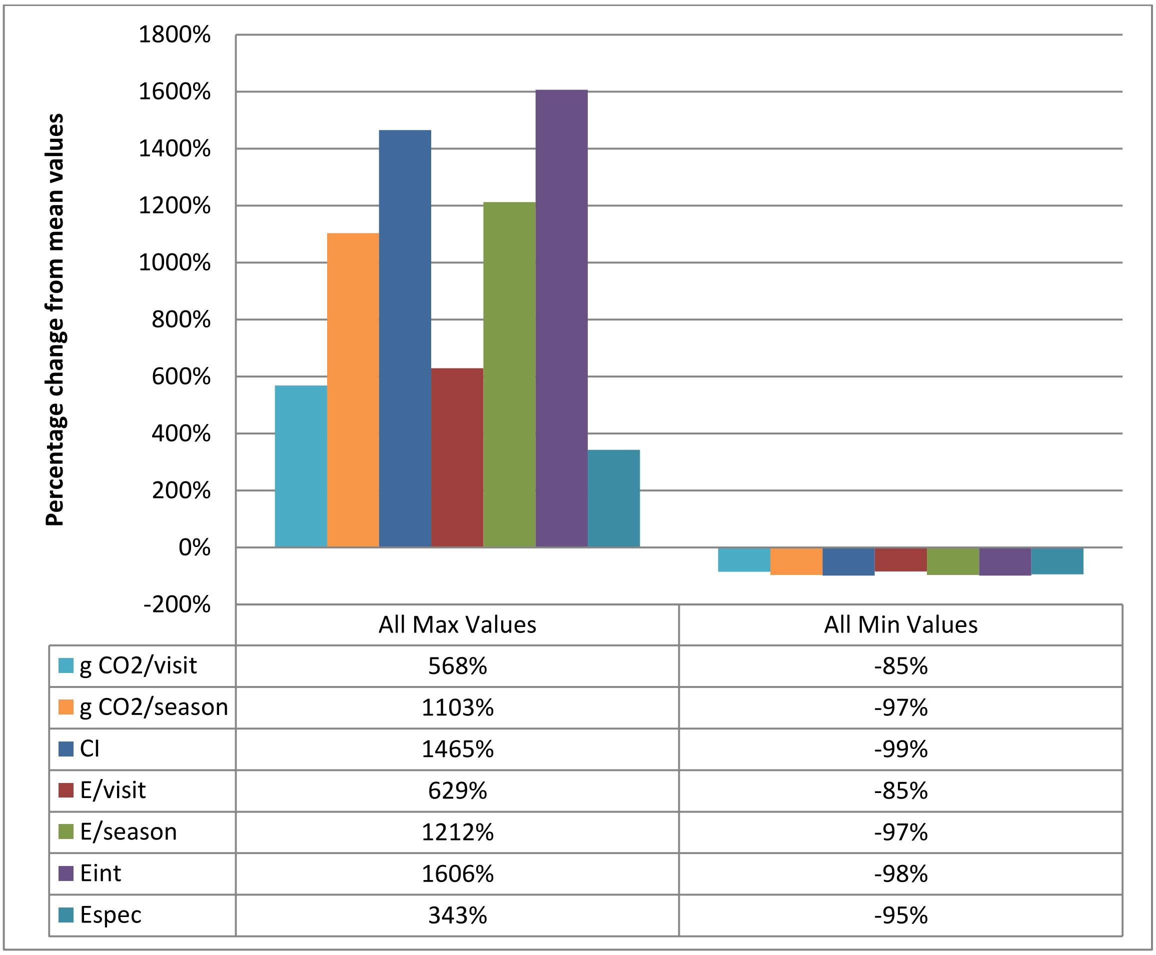
One result that is not obvious from the table is the extent to which adding passengers reduces CF and energy use per kilogram of food. When taking into account additional passengers and the quantity of produce picked up at the same time, the values for CI, E_{int}, and E_{spec} dropped by 14%, 16%, and 12%, respectively. The effect is greater with more passengers, as demonstrated by the respondent who said that they share the vehicle with four others (the most of any respondent). In this case, emissions and energy values decreased by 80%, and for E_{spec} it decreased to the point that it became the lowest value of all respondents. Adding more kilograms of food per visit, driving shorter distances, and driving a more efficient vehicle would have similar outcomes, as will be demonstrated below by the sensitivity analysis for these scenarios.

3.3 Sensitivity Analysis of Driving Scenarios

The sensitivity analysis demonstrates what would happen if every survey respondent adopted the vehicles and driving behaviors of those who maximum and minimum baseline values in

Table 3.2. The mean values are the control. The worst case scenario assumes that everyone drives a SUV-type vehicle, visits forty-two times during the season, drives forty-two kilometers one-way, picks up 2,5 kilograms of food per visit, and drives alone. The best case scenario assumes that all respondents drive a Toyota Prius hybrid, visit only five times per season, drive three kilometers one-way, pick up 12 kilograms per visit, and share the ride with four passengers. Mean baseline values not shown in Table 3.2 are as follows: 23 visits per season, 4,4 kg per visit, and 1,3 passengers. While scenarios may appear extreme, they are not so far from real values for respondents that ranked highest and lowest for emissions and energy use in the survey.

Table 3.3: Sensitivity analysis of worst and best-case driving scenarios. For explanation of abbreviations, see Table 3.2.



	All Max Values	All Min Values
■ g CO2/visit	568%	-85%
■ g CO2/season	1103%	-97%
■ CI	1465%	-99%
■ E/visit	629%	-85%
■ E/season	1212%	-97%
■ Eint	1606%	-98%
■ Espec	343%	-95%

Table 3.3 shows the results of the sensitivity analysis. To help understand what the results indicate it is useful to review the metrics. The first one, g CO_2, is simply a measure of carbon emissions due to driving. It is a function of distance and vehicle emissions factor, but not quantity of food. Driving a SUV-type vehicle gives a 568% increase in emissions, and

because the respondent also makes frequent trips to Øverland emissions accumulated over the course of a season increase to 1103% over the average respondent. The same applies to E per visit and season, except that these are a function of fuel consumption. CI and E_{int} both factor in quantity of food, and the fact that the worst-case scenario picks up so little each visit relative to emissions and energy use by the vehicle is made evident by such significant percentage increases in these categories. Finally, E_{spec} increases by the least amount because it is a function of fuel consumption and load, but not distance driven, and since the quantity assigned to the worst-case scenario is not so different from the mean values (4,4 kg versus 2,5 kg) it does not lead to as significant an increase as in other categories. The best-case scenario demonstrates the extent that respondents could reduce their emissions without giving up driving entirely. CI is reduced by 99% compared to mean and E_{int} by 98%, again demonstrating the effect of quantity on these metrics. Smallest reductions are achieved in the categories of g CO_2 and E per visit.

4 Discussion and Conclusion

4.1 Validity of survey results

There are 340 adult shareholders at ØverlAndel. Of those, a number share the same household, though exactly how many is not known due to the nature of how membership works (individuals sign up for their own share, and all members above fourteen are considered adults even if they still live at home). If half of all members share a household, that makes a sample size of 170. Eighty-one shareholders replied to the survey, giving a response rate of 48%. While this may appear low, it is actually higher than the typical response rate for ØverlAndel's annual evaluation survey (Anja Bruland, pers. comm., 28th January, 2013). Furthermore, with the use of triangulation I was able to confirm some results from the current survey with data gained though the interview with Jolien Perotti and ØverlAndel's annual evaluation (ØverlAndel, 2011b). For instance, the geographical distribution of respondents matches the distribution of shareholders estimated by Jolien Perotti, indicating that results from the survey are representative. What's more, results from the evaluation concerning frequency of visits matched the spread of results from the current survey.

4.2 Setting ØverlAndel in context

4.2.1 Transportation and collection

With a 73% rate of vehicle use for picking up their produce, members of ØverlAndel drive more than the average Norwegian to do their shopping – if picking up produce at Øverland is considered a form of shopping. At 17% they also bicycle more than the average. Respondents drive on average 11 km one-way to pick up their share (the median distance is slightly less at 9 km), and for 64% of respondents it is a dedicated trip. According to Statistics Norway, the average distance driven during one trip (for any purpose) in Norway is 11,1 km, though nearly half of those trips are shorter than 5 km and two out of five are shorter than 3 km (Bøeng 2011). As of 2005, shopping is the reason for 28% of all trips by any mode of transport (an increase of 3% since 2001) and 59% of shopping trips are done by car, 20% on foot, 3% by bicycle, and 5% by public transport (ibid.). The report does not distinguish food shopping from other kinds, which may mean that in practice driving for food accounts for an even smaller fraction of shopping trips. Another report from Statistics Norway cites that vehicle use accounts for nearly 89% of all inland passenger transportation in Norway – and use is on the rise. Energy use *per passenger* and *per ton of goods* has gone down between 1990 and 2009 due to increased fuel efficiency, though passenger kilometers and total energy use for transporting goods both rose by 33% indicating a growth in mobility and trade volume (Monsrud 2009). For comparison, a study by Pretty et al. (2005) estimated in 2000 that 59% of shopping trips in the UK were made with a passenger vehicle, 30% by walking, 8% by bus, and only 3% by bicycle. The study also calculated that shoppers drove an average of 6,4 kilometers to reach the supermarket.

Such a reliance on cars is not surprising in a country where rugged geography and a sparse population hinder the development of an efficient public transportation infrastructure, particularly in rural areas. Øverland, however, is not typical of Norway. Located 16 kilometers outside of Norway’s largest population center, it is well connected by several modes of public transit including a bus that drives past every thirty minutes. As seen in the results, a large portion of respondents live in Oslo, from which it takes approximately thirty-five to forty minutes to reach the farm via public transportation (metro from Oslo Central Station to Bærum, bus to Øverland, then a five-minute walk). The same route takes approximately twenty-fives minutes to drive. The largest group of respondents lives in Bærum, the same municipality in which Øverland is located. Despite living closer, however, it is easier to get to Øverland on public transport from the center of Oslo than from within

Bærum, a more rural municipality. For members living in other rural municipalities in the surrounding area public transportation options are also limited.

4.2.2 Emissions and energy use

Table 4.2.2 shows that CI and energy consumption from transporting food at ØverlAndel are significantly higher than in other food networks, both local and mainstream. The calculations for this study entailed certain estimates and assumptions (though educated ones) making the final results approximations. Mean values for the current study are much higher, which is likely due to the fact that the highest values in the categories for CI and energy use are several orders of magnitude greater than in any other study, particularly in the case of E_{spec}. For this last category (and to some extent for the others) it is unclear if the results on the high end are anomalies or if respondents actually use that much energy to transport their food home. Despite this, results from this case are well within the range of results from other studies, suggesting that the study was carried out in a manner consistent with the literature. As discussed previously, findings in the literature are not always consistent, but in the examples given here there is a high degree of overlap. The only exceptions are results for Van Hauwermeiren et al. (2007) and Kulak (2010) in which results for CI of local and mainstream systems are contradictory (Coley et al. (2008) used different study boundaries and units of analysis than the other studies and thus cannot be compared directly).

Table 4.2.2: Comparison of transportation emissions from ØverlAndel to other studies

	Current Study[1]	**Thomsson & Wallgren, 2005[2]**	**Wallgren, 2006[3]**	**Van Hauwermeiren et al., 2007[4]**	**Coley et al., 2008[5]**	**Kulak, 2010[6]**
CI	89-3076 (935)	-	-	36,69-1557,14 (384,15)/ 25,01-443,56 (117,49)	360	291,4/ 1185
E_{int}	1,03-34,05 (10,68)	0,3/ 5,9	0,2-17/ 0,45-50	0,5-21,27 (5,25)/ 0,34-6,06 (1,60)	-	-
E_{spec}	50-1350 (550)	-	2,4-65/ 0,4-12,5	-	-	-

CI in g CO_2/kg; **E_{int}** in MJ/kg; and **E_{spec}** in MJ/ton-km

[1] Values shown are min, max, and mean (in parentheses) for each category and are calculated based on number of passengers (the value for E_{spec} was converted to MJ/ton-km in order for units to match those used by Wallgren)

[2] Values from local (Järna)/regional (Stockholm) transportation of vegetables

[3] Values are lowest and highest from transportation to farmer's market/conventional food system in Stockholm (unit for E_{spec} in MJ/ton-km)

[4] Values are min and max from transportation to collecting point in local/mainstream food systems in Netherlands with mean values in parentheses

[5] Value is transport emissions per box of vegetables (mix of local and imported) delivered to consumer door in a box scheme in Southern England

[6] Values for locally produced vegetables delivered to consumer by electric vehicle/mainstream vegetables delivered to supermarket – local values include emissions from refining fuels and producing electricity (original results in kg CO_2 for individual items so I averaged values and converted to g CO_2)

It should be noted that all of these studies calculate emissions up to point of collection and do not factor in consumers driving to and from the collection point, with the exception of Coley et al. (2008) and the local value for Kulak (2010) for which food is delivered to consumers. While making a side-by-side comparison unfeasible, it does demonstrate how significant the final shopping trip may be when compared to upstream transportation. However, I was unable to find any studies in the literature that calculate emissions or energy use from this stage. One likely reason is that driving often serves multiple purposes and knowing how much of a trip's emissions and energy use should be assigned specifically to food shopping is a complicated and imprecise calculation wrought with assumptions (Browne 2008). For ØverlAndel, 64% of respondents take only dedicated trips to collect their food. The majority of those who responded that they take multi-purpose trips also make dedicated trips occasionally – for 63% of them it is at least half of the trips. This suggests that the majority of driving to Øverland is solely for the purpose of collecting food or other activities on the farm (e.g., participating in work groups or meetings). However, due to how the survey was carried and the low response rate for questions regarding this topic, I was unable to adjust emissions and energy use to reflect multi-purpose driving and these results cannot be considered as valid. This uncertainty warrants further investigation.

One of the more interesting observations from this case is the wide spread of results for CI and energy use. In fact, the range is equivalent to the difference between transporting food with an electric freight train and an airplane. Transporting goods by electric train, which is considered one of the most efficient modes of bulk transport, has a CI of 69,15 and an E_{int} of 1,03. These values are similar to those of the respondent with minimum values, calculated to have a CI of 89 and E_{int} of 1,03. Transporting by airplane has an E_{int} of 29,4 and CI of 2149,2 and is by far the least efficient mode of bulk transport (Van Hauwermeiren et al. 2007). The respondent with the maximum values (CI of 3076 and E_{int} of 34,05) exceeds those for air freight. In reality, this respondent does not contribute to climate change as much as an airplane because of the effect of radiative forcing, but on a per-kilogram of food basis it is comparable.

4.2.3 Life-cycle carbon "foodprint"

Table 4.2.3 shows results from a selection of LCA studies of various agricultural products. It is not an exhaustive review of food system LCA studies, but does give a general idea of the relative carbon intensity of producing and distributing goods that are commonly available in the supermarket. All the products listed are those that either currently are or can be grown at

Øverland and, at least in theory, all calculations account for both carbon and non-carbon emissions. The table is divided into the three boundaries used for the studies: production (or farm-gate), delivery to retail or regional distribution center (RDC), and delivery to consumer. At one end of the spectrum, survey respondents who have the smallest carbon intensity from driving emit little more CO_2 per kilogram of food than the production of seasonal, outdoor-grown fruits and vegetables. At the other end, emissions are similar to the production of tomatoes in heated greenhouses or even chicken and pork (both of which have GHG intensities ranging from 1350-8800 g CO_2/kg according to Gössling et al. (2011). As noted previously, transportation generally comprises 12-14% of the food system's total carbon footprint (Weber and Matthews, 2008; Audsley et al. 2009; Garnett, 2011). If production emissions at Øverland are assumed to be similar to those listed in Table 1.1.3, and the average carbon intensity of transportation is 935 g CO_2/kg (with a range of 89-3076), it is clear that transport emissions comprise the bulk of the food's carbon footprint for those who drive to Øverland – and may even surpass emissions from both production and transportation of food available through the mainstream food supply chain, including the most energy and carbon intensive plant products and some animal products. Even factoring in distribution, emissions from ØverlAndel are significantly higher in many cases. However, from this table alone it is not possible to calculate how much downstream stages add to the emissions of upstream stages, and certainly not the final shopping trip.

As discussed in the Methods, it is necessary to clarify LCA study boundaries and which activities are included and – perhaps even more importantly – those left out. All the values for production are for production within the country listed. Values for Audsley et al. (2009) are for items produced within Europe and delivered to regional distribution centers (RDC) in the UK. For Nymoen and Hille (2010) values are for CO_2 equivalent per weight of edible product as delivered to nursing homes *or* supermarkets (they made no distinction between the two) and are average emissions of domestic and imported goods over the course of a year. Kulak (2010) calculated emissions from production of fruit and vegetables in community gardens located in a suburb of London and delivered to consumers in an electric vehicle. In some ways, this last one is likely the most comparable to emissions generated by production at Øverland because the scale and type practiced in the community gardens are similar and the final delivery with electric vehicle add minimal emissions. The only other LCA study to include the final shopping trip in their calculations was LRF (2002) from Sweden. However,

Table 4.2.3: Comparison of LCA Carbon Emissions for Food Items

Vegetable/Fruit	g CO2-e/kg			Country	Source
	Production	**To RDC/Retail**	**To Consumer**		
Apples	66			UK	DEFRA, 2007
		430		UK	Audsley et al., 2009
		270		Norway	Nymoen and Hille, 2010
			110	UK	Kulak, 2010a
			820	Sweden	Carlsson-Kanyama and Gonzalea, 2009
Brassicas	295 (cauliflower)			UK	Lillywhite et al., 2007
	220 (broccoli)			Sweden	Angervall, 2006
		480 (cabbage)		UK	Audsley et al., 2009
		116 (cabbage)		Netherlands	Kok et al., 2001
		560		Norway	Nymoen and Hille, 2010
			210	UK	Kulak, 2010
Carrots	46			UK	DEFRA, 2007
	122-234			Denmark	Miljøstyrelsen, 2006
	36			Sweden	Cederberg et al., 2005
		430		UK	Audsley et al., 2009
			370	UK	Kulak, 2010
			420	Sweden	Carlsson-Kanyama and Gonzalea, 2009
Cucumber (greenhouse)	4370			Denmark	Miljøstyrelsen, 2006
Lettuce	602			UK	DEFRA, 2007
		1000		UK	Audsley et al., 2009
			518	Sweden	LRF 2002
Onions	60			Sweden	Cederberg et al., 2005
	79			UK	DEFRA, 2007
	382			Denmark	Miljøstyrelsen, 2006
		480		UK	Audsley et al., 2009
		540		Norway	Nymoen and Hille, 2010
			370	UK	Kulak, 2010
Potatoes	158			UK	DEFRA, 2007
	160			Denmark	LCA Food, 2003
	261-274			Netherlands	Kok et al., 2001
	73-83			Sweden	Cederberg et al., 2005
	100			Sweden	Mattsson et al., 2001
		510		UK	Audsley et al., 2009
		430		Norway	Nymoen and Hille, 2010
			150	UK	Kulak, 2010
			270	Sweden	LRF 2002
Tomatoes (greenhouse)	82 (unheated)			Spain	Antón, Montero, & Muñoz, 2005
	1300			Sweden	Möller Nielsen, 2007
	5900-28500			UK	Williams, Audsley, & Sandars, 2006
	3450-4920			Denmark	Miljøstyrelsen, 2006
		1300		UK	Audsley et al., 2009
		2300		Norway	Nymoen and Hille, 2010
			540 (polytunnel)	UK	Kulak, 2010

Table adapted and modified from Nymoen and Hille, 2010 and Gössling et al., 2010. Where there is a range of numbers, the lower value refers to conventional agriculture and the higher one organic.

these values were cited in Nymoen and Hille (2010) without explanation and the original report is no longer available to confirm methods and system boundaries. What is not clear for any of these studies, however, is the extent to which they account for so-called upstream emissions – inputs like fertilizers, equipment and fuel, or land-use change – all of which can add significantly to a product's carbon footprint (Audsley et al. 2009; Plassman and Edwards-Jones 2009). Another activity that may or may not be included but could add significant emissions is transporting workers to and from processing, distribution, and retail centers, something which is less of a factor for ØverlAndel.

There is a high degree of inconsistency in findings between the studies listed in Table 1.1.3. Even assessments that supposedly follow the same system boundaries for the same goods have vastly different results, and the only two studies to include distribution to consumers have values that are in some cases lower than other studies ending further upstream. This variation could be a result of a number of factors, not least of which is differing production conditions and practices from country-to-country or even farm-to-farm. To illustrate this point, a study examining the climate impact of strawberry production in the UK found that the pre-harvest global warming potential varied from 1,5 and 10,3 tons CO_2 eq/ha/crop, depending on cultivation practices, soil type, age of crop, employment of mulch or polytunnels, and other factors (Warner 2010). Another study that conducted LCAs for organic versus conventional apple production in New Zealand was unable to conclude which system was more environmentally benign because there was so much variation in emissions between individual farms following similar practices; greater, even, than the variation between organic and conventional (Milà i Canals 2003). On top of that, LCA provides only a snapshot of emissions at a given point in time, but is not capable of showing trends. It is no surprise, then, that when system boundaries are expanded horizontally to encompass the entire food supply chain (from inputs to disposal) and vertically to include the global food trade, relatively small differences at each stage and at each scale compound each other to create the variation seen in the literature. For more information about the strengths and limitations of LCA methodology I refer the reader to Garnett (2011) and Schau & Fet (2008).

4.3 Implications of findings

4.3.1 Limitations and reservations

It should be noted that results from this case have certain limitations. For one, the current study is not a LCA for the entire operation and therefore does not account for emissions from all activities. The data on which calculations are based entail certain assumptions and estimations. Furthermore, findings from the literature to which it is compared are often inconsistent and occasionally contradictory. However, it is possible that when factoring in the lack of transport emissions from those members who do not drive and possible reductions in other areas such as production, processing, storage, and lack of infrastructure, ØverlAndel has a lower carbon footprint than other food supply networks. To determine this would have required a much more detailed analysis than was possible for this study.

4.3.2 Balancing of values

While reducing food miles and transportation emissions are important motivations for ØverlAndel and actors in other LFNs, they are not the only ones. In the annual evaluation survey given by ØverlAndel, shareholders expressed a range of values that they feel give membership added meaning (ØverlAndel, 2011b). They were given a choice of ten statements to rank as "important", "partly important", and "not important." The five that ranked as most important were "to support organic agriculture", followed by "access to organically grown vegetables", "connection to where food is grown", and "to get hold of food directly from the producer and outside the conventional market." Least important were "participation in ØverlAndel for its own sake", "showing children where food comes from", and "to ensure that the land is available to all". The three other values ranking in the middle were, "to get vegetables of a quantity and quality that match the price of a share," "to be part of a social community connected to ØverlAndel," and "to ensure that the land is used for food production." Members also had the option to write in their own answers. These responses are spread out over a spectrum of issues that largely mirror the above choices. These values reflect those that are generally seen in the literature as motivations for actors in LFNs and other alternative food networks (Terragni et al. 2006; Lockie 2009).

Interestingly, there is not a single mention of climate as an "added" value in the evaluation, confirming what Jolien Perotti said in her interview about the disparity between members and the organization in their considerations of climate (Jolien Perotti, pers. comm., 4th April, 2012). One example from the literature that may shed some light on this apparent disconnect is the Beddington Zero Energy Development (BedZED) project. Located in a suburb of London, BedZED is UK's largest sustainable community and was designed to reduce the carbon footprint of its residents. By almost all indicators it has succeeded in its goal, from construction through to energy use, waste reduction, and vehicle use. One indicator that has not improved is residents' use of airplanes for travel. In fact, they fly three times more than residents in the surrounding municipality. In a study on the community, the author speculates that this could be due to a few wealthy residents who enjoy international travel; or, more likely, that because utility bills are so low residents have more disposable income to spend on holidays. This is one example of the so-called "rebound effect" in which improvements in efficiency can lead to increased consumption, thus cancelling out the efficiencies gained (Sorrell 2007). Furthermore, the author comments that:

> While the layout of the site and transport facilities provided have obviously changed the approach that many residents take to local mobility, it hasn't translated into a deeper understanding of the impact of transport. This is true more generally of residents' attitudes towards climate change and shows that further measures are needed to adequately reduce their emissions – whether through face-to-face engagement, market incentives or some other means… Residents need more of their essential community facilities and shops within walking distance, and the regional transport infrastructure needs to make the area more permeable for public transport users and cyclists than for motorists (Chance 2009, p. 536)

This statement highlights two critiques about LFNs: 1) That participation does not automatically lead to changes in awareness (or understanding) of the underlying issues nor to changes in behavior; and 2) LFNs are still embedded within an inherently unsustainable context and that without changes to the context they will never fully achieve their goals (Mariola, 2008). While members of ØverlAndel are concerned with sustainability issues such as eating organic food and supporting organic agriculture, do these concerns extend beyond their participation in the CSA? Do they feel that participation exempts them from taking other measures to reduce their ecological footprint? Or, are they constrained by a lack of incentives or infrastructure (such as access to public transit) to make more sustainable choices – even if they have a desire to act on their awareness? It is also possible that climate in general is a concern for members of ØverlAndel, but like many consumers they lack concrete knowledge about the relationships between behaviors and outcomes such as the extent that driving has on their food's carbon footprint (Carrico 2010). These are questions worth exploring in further research.

Climate impact is relatively easy to quantify, whereas other values are less so. For one, participation in the growing and harvesting of food – even if it entails driving – engages consumers and discourages them from becoming "lazy locavores" (DeLind, 2011). It can also be seen as an opportunity for recreation, encouraging physical activity and immersion in nature for the urban shareholders. Supporting organic agriculture, particularly the kind practiced at Øverland, protects biodiversity and the cultural landscape (ØverlAndel, 2011a). Even though showing children where their food comes from ranked relatively low, they are exposed nonetheless and that is a valuable investment in the future.

4.3.3 Scaling-up LFNs: two possible outcomes

As mentioned previously, the CSA movement is growing in Norway. If this trend continues, what would happen to the transportation carbon footprint of LFNs if the ØverlAndel model was scaled up and/or replicated in other areas of Norway (as has already has begun)?The sensitivity analysis gives some insight into how these scenarios may play out. In the worst-case scenario, the LFN continues to develop as it is today – dominated by driving alone long distances to pick up a small quantity of goods. In this scenario LFNs are not sustainable, both in terms of direct climate impact and for the spill-over effects of passenger vehicle use (increased traffic, health and safety costs, costs for maintaining infrastructure, reliance on non-renewable resources).

In the best-case scenario the picture improves, demonstrating that significant reductions are possible. Consumers drive short distances (or not at all) to pick up large quantities of goods that cover a greater percentage of their consumption needs, and they share the ride with others. However, realizing this scenario will take a concerted effort by government and citizens alike and comes with certain practical limitations. For one, reducing distance between consumer and producer entails either consumers moving closer to where food is grown (not very practical) or producers moving closer to where consumers live. To realize the latter option, the CSA model and other LFNs would have to reach a critical mass if they are going to reach the point at which production occurs within 3,2 kilometers of consumers (based on calculations from Coley et al. (2008) and assuming that consumers drive) and the scale of production would have to increase dramatically to cover a larger percentage of consumers' needs. Of course, another option is for consumers to grow their own food. While meeting demand locally is an unlikely prospect given Norway's difficult climate, consumption habits, and disappearance of agricultural land in peri-urban areas, it is not impossible.

Another option to reduce emissions is to expand public and alternative transport offerings. More bicycle paths to encourage bicycling, an expanded network of busses and other collective transport, and incentivizing carpooling can help to reduce driving among consumers. More importantly, this scenario benefits all members of society, not just consumers of local food. Reliance on inefficient transport may be a weak link in local food supply chains, but it is not unique to them. Efforts to reduce driving will have far-reaching ramifications that benefit all. Another possibility is that if there is enough demand for local products, they can be distributed in bulk through established channels to smaller markets located closer to where consumers live, as Marletto & Silling (2010) discussed.

ØverlAndel must consider how they can best balance reducing the carbon footprint of transportation while maintaining other values such as social interaction, participation, and connection to the food. One option would be to deliver food to shareholders or to central pick-up points, but this option conflicts with their practice of self-harvesting. Encouraging carpooling is another option, but that will require shareholders to coordinate busy schedules and sacrifice a certain degree of flexibility. Another possibility is to incentivize taking public transit. This may work for those who have easy access, but not those who live more rurally. Increasing production will reduce the carbon intensity of the food and meet a greater percentage of consumption needs, but this will be limited by storage capacity of shareholders, shelf-life of the produce, and production capacity of the farm. Finally, since there are so many people on the waiting list, it is possible ØverlAndel can establish satellite farms spread around the region. This will keep land in food production, bring production closer to consumers, provide more organic produce to meet increasing demand, and allow more consumers to purchase their food directly from the producer.

4.4 Conclusion

In conclusion, it appears that transport emissions are significant for ØverlAndel and are possibly undermining the organization's goal of reducing the carbon footprint of their operation. Three-quarters of respondents drive to Øverland to collect their food, with the majority of those driving alone and making dedicated trips. The average distance driven to collect food is eleven kilometers one-way. Calculations show that the carbon intensity of food from transportation alone ranges from 89 to 3076 g $CO_2 \cdot kg^{-1}$ with a mean of 1092; energy intensity ranges from 1,03 to 47,4 $MJ \cdot kg^{-1}$ with a mean of 12,64; and specific energy used for transporting the food ranges from 0,11 to 1,35 $MJ \cdot kg\text{-}km^{-1}$. These results are significantly higher than those from transportation in other food networks presented in the literature. Comparing life-cycle emissions from production and distribution of individual food items available through mainstream food supply chains further confirms the significance of emissions due to transportation at ØverlAndel.

The sensitivity analysis demonstrates possible outcomes of scaling up the CSA model and other forms of LFNs. Continued reliance on passenger vehicles for transporting small quantities of food will exacerbate transport emissions, counteracting any reduction in "food miles" and potential carbon offsets elsewhere. Efforts to reduce transport emissions in LFNs include expanding collective transport, encouraging carpooling, delivery of goods to consumers, and expanding production closer to where consumers live – all of which bring benefits to society as a whole. To implement these solutions will take concerted and collective action by government, the business sector, and consumers alike.

Reducing the climate impact of the food system is not only the responsible of participants in LFNs; it is a responsibility of all global citizens. More importantly, efforts to reduce GHG emissions must be made in all sectors, not just for food. While the food system is responsible for up to 30% of all anthropogenic GHG emissions, a much greater share comes from burning fossil fuels to produce energy, in manufacturing and in transportation. Unless action is taken in these other sectors no amount of effort to reduce the impact of the food system will last. However, since everyone must eat, food is a good place to begin.

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