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Research Brief

From the Southwest BC Bioregion Food System Design Project 2016

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Greenhouse Gas Emissions from Food Production in a Regionalized Food System

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Abstract

In this research brief we present findings of our investigation into quantities of greenhouse gases that would be emitted from agricultural food production in the southwest BC bioregion (an area comprising five regional districts in the southwest mainland corner of British Columbia, Canada (Harris et al., 2016)) under scenarios of food system regionalization, conducted as part of the Southwest BC Bioregion Food System Design Project. We include a short description of our methods and highlights from our findings. A key insight is that as we increase production of food in Southwest BC to increase food self-reliance, we also increase the local production of local greenhouse gas emissions. This result can be viewed as an opportunity for Southwest BC producers and consumers to assume responsibility for the emissions associated with the foods we produce locally, and to pursue opportunities to reduce them.

In Canada, agriculture is the second largest contributor to total greenhouse gas emissions.

Why should we measure greenhouse gas emissions related to food systems?

Global agriculture has been identified as the second largest emitter of greenhouse gas (ghg) emissions, at 12% of total global emissions (Smith et al. 2014). In quantity of emissions it is second only to the energy sector, which includes power generation and transport. The main sources of global agricultural emissions are enteric fermentation (digestion) in ruminant animals like dairy cows and beef cattle (40% of emissions), manure left on pasture (16% of emissions) and use of synthetic fertilizers (13% of emissions) (Food and Agriculture Organization of the United Nations 2014).

In Canada, agriculture is the second largest contributor, after energy, to total ghg emissions (Environment and Climate Change Canada 2016). In British Columbia the agriculture sector is responsible for approximately 3% of emissions or 2 million tonnes of carbon dioxide equivalent (CO_2e) emissions per year (BC Ministry of Environment 2014).

The figures above capture only the emissions from agricultural production. Additional food system emissions, mostly CO_2 from fossil fuel use, are emitted in the processing, packaging, and transportation of food. Accurate estimates of these emissions are not yet available at global, national or local scales, but it has been offered that globally the food system contributes as much as half of all anthropocentric greenhouse gases (Moreau, Moore, and Mullinix 2012).

In the Southwest BC Bioregional Food System Design project, we wanted to examine how regionalizing the food system to increase food self-reliance would affect quantities of greenhouse gases emitted from food production in the bioregion.

Methods

Food System Scenarios and Modeling

To explore the outcome of and options for regionalizing the Southwest BC food system in the future, ISFS developed two computational models to estimate current (2011) and future (2050) food production, food self-reliance, environmental impacts, and economic outcomes of various scenarios (Dorward, Smukler, and Mullinix 2016a, 2016b). The models employed two different calculation techniques based on agricultural land use allocation. In the first model (a spreadsheet model), future agricultural land use allocation followed 2011 agricultural land use patterns. In the second model (optimization model), future agricultural land use was reallocated and prioritized to meet food need in Southwest BC, with maximizing Southwest BC food self-reliance as a goal. A key feature of the optimization model is therefore that land is allocated to crops that satisfy the highest level of local food need possible. The underlying assumption in both models was that bioregional consumers choose to purchase locally produced food whenever available (that is locally produced food is first sold to the local market, excess food is for exportation). When regional production cannot satisfy regional demand, importation of that food is necessary.

With these computational models, numerous food system scenarios were generated and five selected for comparison. Each scenario selected is predicated upon an incremental change from the previous scenario, and highlights outcomes of different approaches to the regionalization of the food system by increasing food self-reliance.

The first is the 2011 Baseline scenario (Baseline) which draws upon 2011 statistical data regarding amount of land farmed, land use for crop and animal production, population, and food need

(Dorward, Smukler, and Mullinix 2016a). The Baseline scenario represents our contemporary regionalized food system situation in Southwest BC as we assume that the bioregion's population chooses to consume local products over imported products whenever possible. Therefore the amount of food production for local consumption modeled in the Baseline is likely to be greater than what actually occurred, and the amount of food import smaller.

In the second scenario, 2050 Business-as-Usual Food Production (BAU), future land use levels and the food production mix is the same as in 2011 while population increases by about 60% (Dorward, Smukler, and Mullinix 2016b). This scenario portrays the degree to which regional food need can be satisfied by land based food production in Southwest BC under the pressure of population increases given no changes in land use, production method, and yields. The 2011 Baseline and the 2050 Business as Usual scenarios were both generated by the spreadsheet model, whereas the following scenarios were generated by the optimization model.

The third scenario, 2050 Increase Food Self-Reliance (Increase FSR), represents a future in which farmable land is allocated differently; to the production of crops and livestock that satisfy regional food need and maximize food self-reliance. In this scenario, our theoretical food system becomes increasingly regionalized. Not only do consumers choose to purchase local products over imported products, the producers also aim to produce and process the types of food that would satisfy local food need.

The forth is the 2050 Mitigate Environmental Impacts from Agriculture (Mitigate Impacts) scenario. This scenario builds upon the Increase FSR scenario. It represents a future in which we attempt to alleviate some of the negative environmental impacts from agriculture; specifically reducing nitrogen and surpluses from animal manure[1] and enhancing wildlife habitat quantity, quality, and connectivity (via hedgerows and riparian buffers)[2].

Finally, the 2050 Expand Agricultural Land in Production (Expand Land) scenario represents a future where food self-reliance is increased through reallocating production of foods that satisfy local food need, and by increasing the amount of agricultural land in production. This scenario builds upon the Mitigate Impacts scenario. It shows the gain when we put currently unfarmed agricultural land into production to serve our regional food need, while maintaining our efforts to alleviate some of the negative environmental impacts from agriculture.

While the Baseline 2011 scenario represents the current food system, the other scenarios offer a glimpse into different food system options for our 2050 future. This, however, does not mean that these are our only options. The scenarios are meant for illustrative purpose and to stimulate discussion about our preferred food system future. The five food system scenarios and their assumptions are summarized in Table 1.

Estimating Greenhouse Gas Emissions by Food System Scenario

For each of our food system scenarios, we estimated quantities of ghgs that would be emitted in the bioregion as a result of terrestrial crop and livestock production taking place there.

To determine ghg emissions from crop (fruit, vegetable, legume, oilseeds, and grain) production in the modeled future scenarios and the baseline year, we multiplied the ghg emissions per tonne of production of each crop by the tonnes of each crop produced in Southwest BC, and

[1]Nitrogen and phosphorus come from livestock manure. Excess amount of these nutrients occur in the soil may act as environmental pollutant. For more information on this topic, see Smukler (2016).
[2]Compared to unfarmed areas, farmed land provides less habitat capacity for wildlife. However, if hedgerows and riparian buffers are introduced on the farms, they could provide sanctuary and allow wildlife to travel safer. For more information on this topic, Mullinix et al. (Mullinix et al. 2016).

TABLE 1: Summary of five theoretical food system scenarios modeled in the Southwest BC Bioregion Food System Design Project and reported in this brief

SCENARIO	TYPE OF MODEL	FARMLAND USE	POPULATION (MILLION)	FOOD NEED (MILLION TONNES)	FARMLAND MODELED (MILLION HECTARES	ENVIRONMENTAL ENHANCEMENTS
2011 BASELINE	Spread-sheet	As Statistics Canada reported for 2011	2.7	2.6	101,000	No enhancements
2050 BUSINESS-AS-USUAL FOOD PRODUCTION	Spread-sheet	As in Baseline Scenario	4.3	4.2	101,000	No enhancements
2050 INCREASE FOOD SELF-RELIANCE	Optimization	Reallocated according to regional food need	4.3	4.2	101,000	No enhancements
2050 MITIGATE ENVIRONMENTAL IMPACTS FROM AGRICULTURE	Optimization	Reallocated according to regional food need	4.3	4.2	101,000	Nigrogen balance and habitat enhancements implemented
2050 EXPAND AGRICULTURAL LAND IN PRODUCTION	Optimization	Reallocated according to regional food need	4.3	4.2	165,000	Nigrogen balance and habitat enhancements implemented

summed emissions from each crop to reach a scenario total for crops. The following sources and types of emissions were accounted for:

- Nitrous oxide (N_2O) from manure or synthetic fertilizer applied to crops calculated based on nitrogen fertilizer recommendations from BC Crop Production Guides (BC Ministry of Agriculture 2014; Yang et al. 2007) and following the method for calculating emissions from nitrogen fertilizer application from the Intergovernmental Panel on Climate Change (De Klein et al. 2006).

- Carbon dioxide (CO_2) from fossil fuel use on farm was calculated based on quantities of diesel, gasoline and natural gas use per unit crop production, determined from a range of North American sources (Agriculture and Agrifood Canada. 1999; Canadian Agricultural Energy End Use Data & Ananlysis Centre 2000; UC Agricultural Issues Center (University of California - Davis) 2016; USDA 2008; Wong and Hallsworth 2012).

To determine ghg emission from production of livestock products (dairy, egg, poultry, beef, pork and lamb) we multiplied the ghg emissions per tonne of production of each livestock product by the tonnes produced in Southwest BC, and summed emissions from each livestock product type to reach a scenario total. The following sources and types of emissions from livestock production were accounted for:

- Methane (CH_4) from enteric fermentation in ruminant livestock (beef and dairy cattle, sheep and pigs) using Canadian and BC values as available (Environment Canada 2011; Ominski et al. 2007).

- Emissions from manure management including methane (CH_4) and nitrous oxide (N_2O) (Environment Canada 2011) assuming BC manure management systems described by Statistics Canada (Statistics Canada 2003) and concentrations of manure N per animal type from Hoffman and Beaulieu (2001).

- Nitrous oxide (N_2O) from manure or synthetic fertilizer applied to livestock feed crops in Southwest BC, based on nitrogen fertilizer recommendations from BC Crop Production Guides (BC Ministry of Agriculture 2014; Yang et al. 2007) and following the method for calculating emissions from nitrogen fertilizer application from the Intergovernmental Panel on Climate Change (De Klein et al. 2006).

- Carbon dioxide (CO_2) from fossil fuel use on farm to produce livestock feed crops was calculated based on quantities of diesel and gasoline use per unit crop production (Agriculture and Agrifood Canada. 1999; Canadian Agricultural Energy End Use Data & Ananlysis Centre 2000; UC Agricultural Issues Center (University of California - Davis) 2016; USDA 2008) and assuming average BC feed requirements (Statistics Canada - Agriculture Division 2003).

We report here on scenarios in which feed imported from outside the bioregion was available for Southwest BC livestock production. Because our account is for ghg emissions produced in the bioregion, emissions associated with imported feed grain for livestock are not included.

To sum emissions by scenario in order to compare across food types and between scenarios, all emissions were converted to CO_2 equivalent (CO_2e) using conversion factors from the BC Ministry of Environment (BC Ministry of Environment 2013).

Results

Figure 1 shows the average locally emitted greenhouse gas emissions per tonne of food produced, by food type. The purpose of the average values is to show relative emissions among different food types. Among livestock products, beef and lamb have the highest per tonne emissions. Fossil fuel energy use in production of greenhouse vegetables (as opposed to field grown vegetables) contributes to the relatively higher emissions from vegetables compared to fruits.

In 2011, approximately 1 million tonnes of food was produced in Southwest BC. We calculated that just over 800,000 tonnes of CO_2e was emitted as a result. Given the agriculture sector in BC emits over 2 million tonnes of CO_2e emissions per year (BC Ministry of Environment 2014), Southwest BC agriculture as we have accounted for it here makes a large contribution to the province's agricultural ghg emissions[3].

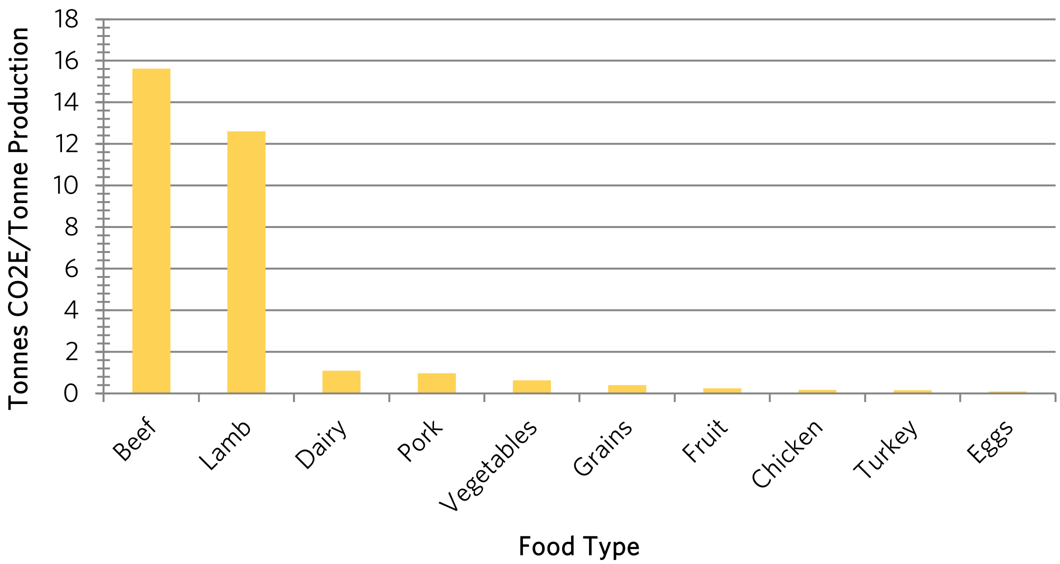

Figure 1: Average greenhouse gas emissions (tonnes CO_2e) in Southwest BC per tonne of local production, by food type

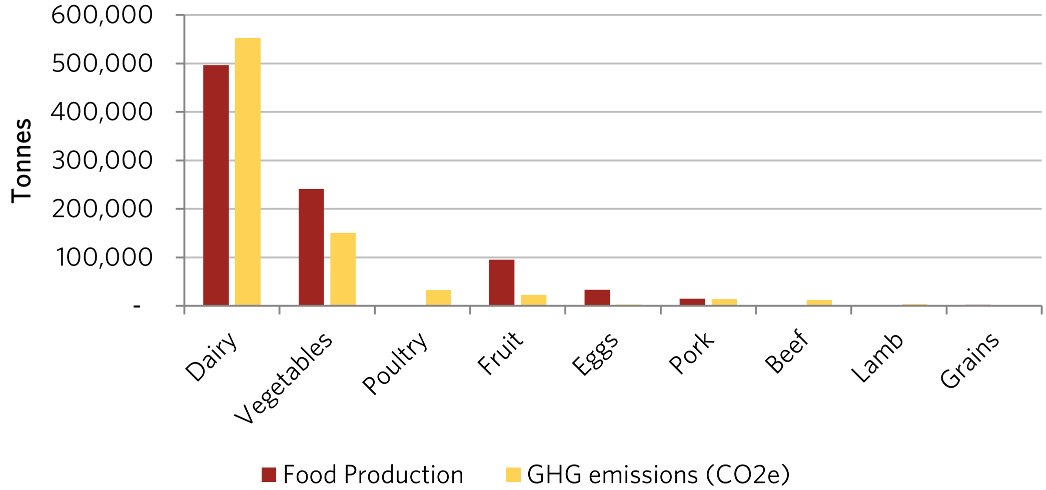

Figure 2: Total food production and total greenhouse gas emissions in Southwest BC in the 2011 Baseline and 2050 Business as Usual Scenarios (values equal in these sscenarios) (tonnes)

Of all food types examined, dairy was produced in the largest quantity and emits the most CO_2e at over 80% of production emissions. In the BAU scenario, the types and quantities of food commodity produced are the same as in the baseline year 2011 (Figure 2). Therefore, the ghg emissions are also the same. In all three of the other scenarios, more tonnes of food commodity are produced and more ghgs are emitted in the bioregion (Figure 3).

Figure 4 shows the tonnes of food commodity by type and the associated ghg emissions for the Increase FSR scenario, the Mitigate Impacts scenario and the Expand Land scenario. For further explanation of the land use and crop production in each scenario that drive these GHG outcomes, please refer to Mullinix et al. (2016).

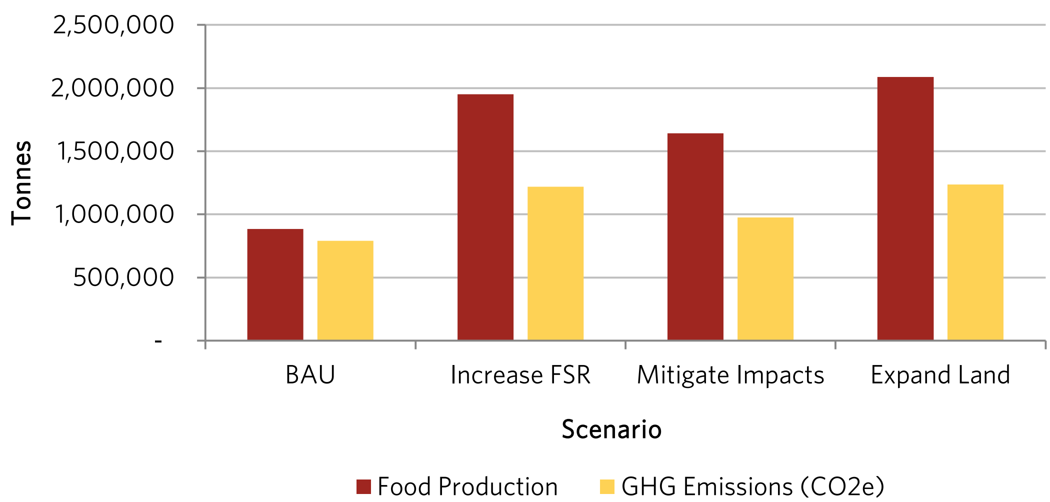

Figure 3: Total GHG emissions and food production in Southwest BC, by scenario (tonnes)

[3]Our estimation of total greenhouse gas emissions from agriculture includes approximately 170,000 tonnes of emissions from stationary on-farm fossil fuel combustion and vehicle emissions. The BC Ministry of Environment does not include emissions from those sources in its estimate of BC's agricultural emissions, rather counts them in the stationary combustion and transportation sector inventories.

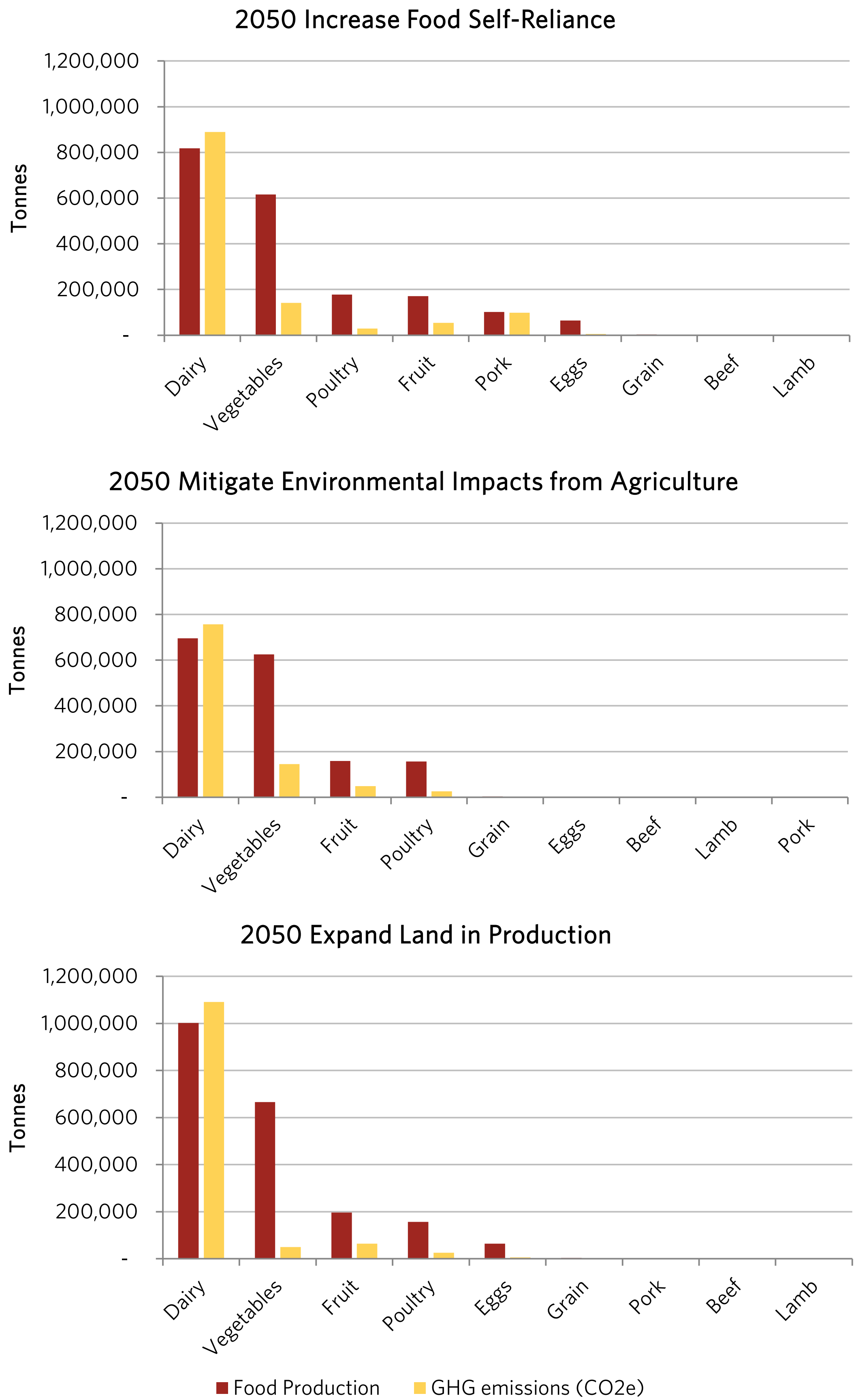

Figure 4: Total food production and total GHG emissions in Southwest BC, 2050 Increase Food Self-Reliance, Mitigate Impacts, and Expand Land Scenarios (tonnes)

Bioregional consumers can reduce emissions associated with local food production by limiting consumption of high emission foods such as beef and lamb.

Discussion and Conclusion

The results of our study show that localizing the food system in Southwest BC increases local emissions of greenhouse gases, assuming no changes to dietary preferences or production methods. When Southwest BC's available farmland is reallocated to produce foods that increase regional food self-reliance, more tonnes of food are produced, more fertilizer is used, more on farm fossil fuel use occurs, and when more animals are present more livestock related ghgs are emitted. It is important to note that fossil fuel emissions associated with foods we consume occur no matter where those foods are produced, be it locally or outside the bioregion. Therefore, the increase in local emissions from food system regionalization can be seen as an opportunity to take responsibility for emissions associated with our food consumption choices. Bioregional producers and consumers can pursue avenues toward reducing emissions associated with local food production and consumption, such as organic and low input crop production methods, and dietary changes that limit consumption of high emission foods (Mullinix et al. 2016).

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About ISFS

The Institute for Sustainable Food Systems (ISFS) is an applied research and extension unit at Kwantlen Polytechnic University that investigates and supports regional food systems as key elements of sustainable communities. We focus predominantly on British Columbia but also extend our programming to other regions.

About the Southwest BC Bioregion Food System Design Project

The Southwest BC Bioregion Food System Design project was conceptualized at ISFS in 2012 and concluded in 2016. The project was conceived as a "research project within a research project," with the broad goals of developing a method to delineate the interconnected economic, food self-reliance, and environmental stewardship potentials of a bioregional food system and applying the method to the Southwest BC bioregion. To our knowledge, this project is the first of its kind. Project research briefs are one means used to present project findings. They are intended to report detailed, topic specific project methods and results. For other research briefs from the project, as well as the project report and summary, and peer-reviewed publications, please visit kpu.ca/isfs.

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