The Climate Impacts of Craft Chocolate:

A Life Cycle Assessment with Ecolabel and Inset Proposals for Carbon Neutrality

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Introduction

A special report published in October of 2018 by the Intergovernmental Panel on Climate Change (IPCC) laid bare the dramatically different impacts that could be expected from 1.5 ℃ and 2 ℃ of global warming. The impacts of 2 ℃ in global warming are so severe that they incentivize a 45% reduction in net global emissions from 2010 levels by 2030 with additional declines to net zero by the year 2050 in order to keep global average temperatures from rising more than 1.5 ℃ over preindustrial levels. Fundamental and fast paced economic transitions are required around the world to reach these aggressive targets (IPCC, 2018). Food sector activity alone accounts for between 25 to 30% of global greenhouse gas emissions (Shukla, et al., 2019). Producers of food products who are concerned about their contributions to global warming or see their carbon footprints as nascent liabilities in a marketplace that is becoming increasingly sensitive to the threat of climate change can employ several established methodologies to mitigate emissions. The first such method is to conduct a life cycle assessment of their product's GHG emissions from cradle to grave. Life cycle assessment is an established and standardized method of analysis for environmental impacts which can reveal relationships between food production systems and the depletion of natural resources. Such an inventory can enable companies to address emission hotspots through changes in their production processes where possible and carbon offsets for activities not amenable to innovation. Companies can then communicate their inventories to the marketplace through ecolabels and ESG statements which establish criteria for internal carbon accounting and mitigation.

Chocolate is a food product whose environmental impacts reflect the complexities of its supply chain. Cacao, the fruit whose seeds are used to make chocolate, grows exclusively in tropical regions but is consumed primarily in Europe and the United States. While the role of transportation in globalized food systems is no longer assumed to be primary, the Spanish agrifood system demonstrates that this aspect of the food product life cycle does at times account for a majority of emissions (Infante-Amate, 2018). A recent life cycle assessment of Ecuadorian chocolate as a global agrifood system came to the conclusion that transportation can negate the environmental benefits of organic cacao production (Pérez-Neira, 2020). Agricultural activity related to food production is responsible for approximately 80% of deforestation throughout the world (Hosonuma, 2012), and some scholars have reached the conclusion that agricultural production is the chocolate life cycle phase with the largest carbon footprint (Ntiamoah, 2008). Twelve dominant companies in the chocolate and cocoa industry have made a collective commitment to end deforestation in the Ivory Coast and Ghana (Foundation, 2017) related to their supply chains. A comparison of four farming methods in Guayas, Ecuador – “traditional, semi-intensive, technified, and organic,” elucidates the differences in energy efficiency among management strategies (Pérez Neira, 2016). The first cradle to grave LCA to be done on chocolate production emphasized the energy demands of the manufacturing plant located in Northern Italy where a trigeneration system uses natural gas to provide electricity, heating, and cooling with greater efficiency (Recanati, 2018).

The craft chocolate industry, characterized by small scale artisanal production methods, seeks to preserve the flavor profiles of cacao beans from single origins and has experienced exponential growth since its inception in the 1990s (Cadby, 2021). Associative Sustainable Business Models are common in the craft chocolate industry where firms seek to collaborate with individual farmers and grower cooperatives to optimize economic, environmental, and social outcomes throughout supply chains for a value-added food product (Gallo, 2018). There is a dearth of literature, however, concerning the life cycle impacts of craft chocolate production. Given the small-scale nature of these enterprises, it is possible that inefficiencies of scale may negate the environmental benefits of the sustainably produced cacao for which craft chocolate makers and consumers pay premium prices. Life cycle assessments of craft chocolate production are necessary to quantify the comprehensive emissions generated by bean to bar companies.

LCA is all the more essential to transparency in this market as there are at present no quantitative assessments such as Environmental Product Declarations or Product Category Rules available to the chocolate sector (ISO, 2021). The International Cocoa Organization Secretariat's five-year strategic action plan for 2019-2024 establishes contributions to Sustainable Development Goals as one of its primary aims (ICCO, 2021). However, industry certifications usually involve weaker governance than those from public institutions such as non-governmental organizations (Benkeser, 2018). Chocolate companies can avail themselves of private climate impact evaluations, but according to the International Trade Centre's Standards Map, there are no public institutions to certify chocolate life cycle emissions. The European Union's Product Environmental Footprint pilot programs provide potential models for public entity verification of product impacts, and the UK Carbon Trust offers product footprint certification on a global basis through a combination of private leadership and public funding.

There are four main certification schemes that dominate the chocolate sector: Rainforest Alliance, Organic, Fairtrade, and UTZ. Together, UTZ and Rainforest Alliance have a combined production area of 2.7 M hectares after introducing a ban on dual certification in Cote D'Ivoire and Ghana

(UTZ, 2021). The Rainforest Alliance stores 150 tons of carbon per hectare on its certified coffee farms in Nicaragua, compared with 82 tons per hectare on non-certified farms, by training farmers in the practice of agroforestry and requiring other best practices (Haggar, 2017). Certified cacao farms contribute to the enhancement of carbon stocks as well through increases in shade trees density (Dawoe, 2016), yet neither Rainforest Alliance nor UTZ provide carbon storage data as part of their certifications. Certifications such as these and other independent initiatives undertaken by private companies represent a more holistic approach to sustainability than do product carbon footprints in so far as they incorporate economic and social development metrics. Product carbon footprints for their part provide rigorous quantifications of CO_2 emissions related to specific phases of production and thus precise measures for climate change mitigation. With their focus on a given unit of output, product carbon footprints also incentivize efficiency throughout supply chains (Plassmann, 2018). The British Carbon Trust's "Reducing CO_2" label requires constant innovation to achieve documented reductions in participant emissions at regular intervals.

Craft chocolate companies typically incorporate social and economic measures of sustainability directly into their business models by collaborating with cooperatives that provide training in best practices to small scale cacao farmers. These cooperatives promote agroforestry and are often certified organic, but their primary purpose is to provide smallholder farmers with access to the specialty cacao market where their beans can be sold at premium prices. As the primary value add-on of craft chocolate production is the preservation and cultivation of cacao flavor profiles, the industry places great emphasis on bean origin. This emphasis engenders a virtuous, market-based relationship between consumers and farmers which has influenced chocolate supply chains throughout the industry as a whole (Cadby, 2021). Given the multidimensional nature of their sustainability initiatives as well as their smaller scales and associative business models, how are craft chocolate makers to approach ecolabels?

Another ecolabel from the British Carbon Trust, carbon neutral certification, ensures that the sum of an organization or product's CO_2 equivalent GHG emissions are offset by natural carbon sinks and/or credits (Trust, 2021). This certification is based on PAS 2060, a criterion for carbon neutrality that enjoys international recognition. PAS 2060 was formulated by the British Standards Institution, a non-profit Royal Charter company that was also instrumental in establishing the International Standards Organization. Carbon neutrality, according to this standard, signifies that no additional or new GHG emissions are introduced into the atmosphere.

Carbon offsets, though commonplace in a variety of cap-and-trade programs, have generated considerable controversy. The Kyoto Protocol's offset program, the Clean Development Mechanism, was criticized for crediting numerous 'non-additional' projects that would have happened on their own without income from carbon credits, inflating reduction estimates with high emission baseline scenarios, and creating perverse incentives related to refrigerant production. One proposed solution to these concerns was to replace project by project additionality testing and baseline determination with standardized criteria or protocol (Italy, 2014). California adopted this approach with a new compliance offset program which controls for quality through protocol to enforce standards across all projects. The state chartered a voluntary offset developer, Climate Action Reserve, to implement the new program in which all qualifying projects meet certain eligibility criteria. Credit inflation related to project additionality is controlled for in California's program through stringent baseline scenarios (Bento, 2016). Despite this standardized protocol, researchers who participated in program development argue that despite best practice protocol, carbon offsets still involve uncertainty which can result in over-crediting and thus can be regarded as government regulated incentive programs rather than verified measures of emissions reduction (Haya, 2020). Firms may opt for insetting instead of offsetting by sponsoring positive actions related to their own supply chains. Insets are well suited to craft chocolate company business models which are associative, transparent, and traceable by nature but must be structured appropriately to avoid neo-colonial power dynamics (Larsen, et al., 2018). This study will propose an inset program for the craft chocolate company in Atlanta that promotes democratic norms in countries of origin and overcomes ethical concerns related to carbon offsets.

Methods and materials

This study will utilize life cycle assessment methodology to analyze GHG emissions related to the production and consumption of a craft chocolate whose factory is located in Atlanta, Georgia.

Goal and scope definition

A cradle to grave approach will be taken beginning with cacao production in four origin countries: Nicaragua, Peru, Tanzania, and Uganda. These are the cacao origins currently used by the craft chocolate company whose representative dark chocolate products are comprised of two ingredients: cacao and sugar. Their sugar is sourced from a Brazilian sugar plantation for which a life cycle assessment of GHG emissions has already been conducted and on which this LCA will rely for information regarding that segment of the supply chain. The climate impacts of foil and wrapper production along with their transportation to the chocolate factory are assessed as well.

Functional Unit, system boundaries and scenarios

The Functional Unit analyzed is a 75 g chocolate bar with wrapper and foil. This unit's life cycle is assessed from cradle to factory gate in the following phases: agricultural inputs to farm gate, farm gate to cooperative, cooperative to port, port to port, port to factory, chocolate production and packaging. Four different scenarios are considered for cacao production, each with their own corresponding transportation routes from farm gate to factory. A fifth transportation route for sugar is considered in this phase as well, and all scenarios incorporate storage demands prior to production. There is one system process for manufacturing in which cacao is sorted, roasted, winnowed, ground with sugar and then conched in the same grinder for 2-3 days before being tempered, set to cool in molds, and wrapped on site by hand. Three scenarios exist for consumption: retail involves purchases at the factory itself, distribution covers the delivery of wholesale orders to local vendors, and shipping relates to deliveries through the Shopify platform. This LCA does not take these scenarios into consideration, nor does it attempt to account for end-of-life scenarios. Options for ecolabeling are discussed and a label appropriate to the craft chocolate company is proposed with design details. An inset scheme appropriate to the Atlanta company but viable for other artisanal chocolate makers is also proposed with implications for the industry's supply chain.

Data Sources

Primary data are used for all phases of assessment. Information is provided during the summer of 2021 by four relevant cacao cooperatives, the sugar supplier, three trading companies who are responsible for transportation from farm gate to factory, and the Atlanta craft chocolate company itself. Shipping and related packaging data is provided through the Shopify platform, though these activities are not considered in this assessment. Information on chocolate foils and wrappers are obtained from their manufacturers and industry associations. Transportation is calculated using GREET models specific to countries of origin for a well-to-wheel approach which includes emissions from the movement of goods as well as the production of fuel. Ecolabel data is drawn from the ITC Standards Map, relevant academic literature, and interviews with craft chocolate makers. Inset calculations are based on relevant scientific literature. For reference, the PUR Project and related International Platform for Insetting are examined as possible models.

Life Cycle Inventory

There are four cacao origins under consideration in this life cycle assessment. These origins are divided evenly between Africa and Latin America. All four origins represent cacao cooperatives which collect wet cacao from small landholders who raise cacao in concert with various other food crops. The primary concern of these cooperatives is to provide small farmers with access to the specialty cacao market where their product can be sold for premium prices. Cooperatives achieve this goal not only by amassing enough cacao seeds to sell them as a bulk commodity but also by fermenting those seeds. Fermentation transforms seeds to beans and is a determining factor in cacao flavor profiles which constitute the primary value add on for bean to bar chocolate production. Farm management does not involve the use of irrigation infrastructure as farmers employ traditional methods and do not have funds for metal piping. Farmers in the Peruvian cooperative Pangoa do utilize a somewhat more technified management system, but in all other origins the farm tool of choice is a machete. Chemical use is also absent for economic reasons in Matagalpa, Nicaragua and for the sake of organic certification in the other three cooperatives.

Transportation from farm gate to fermentation varies with each origin. The cacao cooperative Kokoa Kamili is located in the Kilombero Valley of Tanzania where it uses 150 cc motorbikes to collect wet cacao from individual farms and pickup stations for transportation to its fermentery. Fuel efficiencies for these and other vehicles is estimated based on real world performance data (EPA, 2021). For the calendar year 2020, Kokoa Kamili used 6000 liters of fuel to travel this 15 km circuit. Fermentation takes place in a 150 m^3 pre-existing cinder block structure containing banana leaf and rice bag boxes under a tin roof; 250, 3 by 1m drying beds each made with locally sourced timber and a rubber wire mesh are used to sun-dry the beans before they are manually packed into 60 kilo jute sacks which are made in Tanzania. Diesel Mitsubishi Fuso trucks are then used by a shipping broker to transport 13 tons of cacao at a time 500 km to Dar es Salam where the beans are stored in a warehouse without lights or temperature control for an average of two months before traveling an additional 12 km to port. Shipments then travel 8420

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km by sea from Dar es Salam to Pennsauken, NJ (Sea-Distances.Org, 2021); emissions for this mode are assumed to be 15 kg CO_2 equivalent per km/ton (IPCC, 2014). This system was used to transport 180 tons of cacao in 2020.

Table 1

Farm to Co-op to Port	150 cc motorbike	Pick-up truck	Canter	Fuso	Unit
Nicaragua		11.4		14.2	Liters/ton
Tanzania	33.3			6.18	Liters/ton
Uganda			0.352	21.9	Liters/ton

Latitude Trade Company in Kampala, Uganda uses Mitsubishi Canters to transport as much as 3-4 metric tons of wet cacao on average from centralized pickup stations in farming villages to a field office in Bundibugyo. The village of Nyahuka is 13 km from the field office and represents the most remote collection point. From Bundibugyo, an average load of 8 metric tons, wet cacao, is then transported 152 km by Mitsubishi Fuso to the cooperative's fermentery in Kasese. Box fermentation and solar drying are used to produce dry cacao in off grid facilities. This cacao is then transported in average loads of 14 mt by Fuso, or empty container trucks returning from the Democratic Republic of Congo, to Kampala. For the final 1,177 km from Kampala to Mombasa, container trucks carry average loads of 17 mt dry cacao. Once 200 mt of cacao have been brought to port, their passage from Mombasa to Pennsauken, NJ is only slightly shorter than that from Dar es Salam at 8280 km (Sea-Distances.Org, 2021). In 2020, 550,000 metric tons of wet cacao were transported along this route.

Cacao Bisiesto used a 125,000 btu propane heater to dry 40 tons of fermented cacao in 2020. This cacao was collected from small scale farmers in Matagalpa, Nicaragua by pickup trucks that traveled a total of 1800 km for the year. The heater consumed 340 hours of electrical energy for the year and 8 tanks filled with 100 pounds of propane each. After fermentation in Matagalpa, cacao travels 350 km to the port of El Rama in heavy duty trucks – an uncommon export route which avoids the Panama Canal. From El Rama the beans are shipped 1170 nautical miles as ocean cargo to the Port of Everglades in Florida (Sea-Distances.Org, 2021). These shipments then proceed by heavy duty truck to another craft chocolate company in Asheville, NC and from thence to Atlanta for a total distance of 996 miles; cacao from Peru follows the same land route to Atlanta after a journey of some 2596 nautical miles from Callao to Port of Everglades (Ibid.).

As climate change has forced coffee production onto higher elevations in Peru, the Pangoa cooperative has responded by converting farms at lower elevations to cacao cultivation. These farms employ organic agroforestry but require some additional inputs for conversion to cacao production such as the construction of trellises and the use of seedlings grown in nurseries. In addition, farming practices involve the use of chainsaws in what is a more technologically intense management style. A recent life cycle assessment of cacao cultivation, fermentation, and transportation to port from the Pangoa cooperative concluded that 0.37 kg of CO_2e are emitted per kg of cacao for this entire process (Albornoz, 2019).

Sugar is sourced exclusively from the Balbo Group's Native Green Cane Project which is in the northeast region of Sao Paulo, Brazil. The project has been certified organic since 1997 and includes reforestation initiatives along drainage canals which together with crop rotation and composting practices have provided habitat to increase biodiversity in the region (Miranda, 2021). Sugarcane bagasse is combusted in high efficiency boilers that are free of sulfur emissions at the company's plant in Sao Francisco. In 2010, these boilers produced enough steam to generate 218 GWh of electricity in a cogeneration project that has been analyzed and approved under the Kyoto Protocol's Clean Development Mechanism – 143 thousand tons of carbon credit trades were enabled by this project between 2002 and 2010 (UNFCCC, 2004). For the period May 2006 to April 2007, an inventory commissioned by Native evaluated GHG emissions attributable to the agricultural production of cane, industrial production of sugar, and transportation to various ports (Seabra, 2021). Net emissions for all these activities amounted to 432.47 kg of CO_2 emissions per ton of sugar transported to New Jersey. The evaluation is comprehensive in so far as it accounts for the manufacture and maintenance of farm and factory infrastructure as well as fuel production from well to pump. From South Plainfield, NJ to the craft chocolate factory in Atlanta, one ton of sugar travels 865 miles by heavy duty truck.

Chocolate Production

The length of time required for each stage of the production process varies by origin as the beans of each region have different characteristics. A vibrating motor is used to sort the cacao which is then roasted in a Royal Convection Oven before being cracked with a Dewalt Drill and then winnowed with the help of a vibrating motor, shopvac, and CoolTron fan. Cacao shells are composted offsite and their contents, or nibs, are ground together with sugar in a Cocotown Grinder for 2-3 days. At this point the chocolate is preserved in blocks to be melted down later in a UNICA Tempering Machine. Bars are cooled in their molds within an air-conditioned cabinet before they are wrapped in foil and paper. Foil is sourced from Hauppauge, NY in orders of 50,000 sheets per shipment; wrappers are made from recycled paper in Glen Falls, NY with 100% hydroelectric power. Hairdryers are used to distribute cocoa butter evenly across all chocolate molds as well as to melt down chocolate in the grinders.

Table 2

Hours/Stage	Equipment	Watts	Nicaragua	Peru	Tanzania	Uganda
Sorting	Motor	30	2.15	1.85	2.25	2.05
Roasting	Oven	680	1.33	1.83	1.67	1.67
Cracking	Drill	1020	0.17	0.17	0.17	0.17
Winnowing	Motor/Shopvac/Fan	30, 1080, 18	2.25, 2.25, 2.25	2.25, 2.25, 2.25	2.25, 2.25, 2.25	2.25, 2.25, 2.25
Grinding	Grinder	2590	72	96	72	72

Tempering	Unica/Oven/Dryer	4000, 680, 1100	4, 1, 75	4, 1, 75	4, 1, 75	4, 1, 75
Cooling	Air Conditioner	1400	1	1	1	1

Results

Total GHG emissions for this craft chocolate range from 0.23 - 0.32 kgs depending on cacao origin per 75 g bar with foil and printed wrapper. For 1 kg of unwrapped chocolate, GHG emissions total 3.1 – 4.3 kgs. Emissions associated with chocolate production in Atlanta were greater than those related to the farming, transformation, and transportation of agricultural inputs. For cradle to factory GHG emissions per 75 g bar it is necessary to calculate impacts from sugar and cacao according to the relevant darkness of chocolate while bearing in mind that 1 kg of dried beans will provide no more than 70% of their weight in nibs for production purposes.

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Table 3

75 g bar	Nicaragua 72%	Peru 70%	Tanzania 73%	Uganda 75%
Cradle to Factory	0.0175	0.0381	0.0268	0.0237
Wrappers	0.021	0.021	0.021	0.021
Production	0.1948	0.2536	0.273	0.273
kg GHG/bar	0.233	0.313	0.320	0.317

Based on data from a recent LCA of chocolate made from cacao grown with the use of organic agroforestry in Guayaquil, Ecuador (Pérez-Neira, 2020), a value of 0.0235 kg GHG was attributed to organic fertilizers per kg of cacao. No meaningful emissions could be attributed to fermentation in either Tanzania or Uganda. Electricity consumption was assumed to emit 0.450 kg CO_2e per kWh in Nicaragua (IRENA, 2017), and emissions from the propane for Cacao Bisiesto's heating unit were derived through stochiometric analysis. Transportation activities were modeled using GREET to provide both pump to wheel and well to pump emissions from each vehicle type in each country. To calculate GHG emissions related to electricity consumed in the production of chocolate, the Energy Information Administration's monthly report for Georgia provided a current breakdown of the state's electric power generation by source whose emissions could then be estimated through stoichiometry (EIA, 2021). Given the seasonal fluctuations in electric power generation, a value of 0.3 kg CO_2e/kWh derived from the EIA's March 2021 breakdown was increased to 0.4 – a figure which accounts for greater emissions from power generation in winter and summer. The aluminum association's Environmental Product Declaration for primary ingot was used to estimate emissions from the manufacture of foil (Stout, 2014).

Ecolabel Proposal

The data identified in this LCA that is consistent across all single origin bars may be too complex for the average consumer at point of sale. A quick response, or QR, code accompanied by the statement "carbon neutral" could quickly communicate the craft chocolate's carbon footprint while also providing consumers with a link to the claim's underlying data. For design purposes, the word carbon could appear above the QR code followed by the word neutral below it - all within the boundaries of a rectangular label. This chocolate company's distinctive cacao logo could be included and made to overlap slightly with the QR code's lower right quadrant as a visual clue to its contents. A shadow cast by the cacao logo could extend below the QR code's lower left quadrant to draw the consumer in with an illusion of dimensionality.

Inset Proposal

To achieve carbon neutrality, the Atlanta craft chocolate company can purchase Renewable Energy Credits, or RECs, through Georgia Power's Simple Solar Plan. Solar farms in Georgia are issued

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a REC for every MWh of electricity generated and delivered to the utility's grid. RECs function like deeds, giving the solar farms property rights to the environmental and social benefits of renewable power generation (EPA, 2021). Small businesses like the craft chocolate company in Atlanta can then purchase those RECs for 1 additional cent per kWh of monthly energy consumption and claim those benefits for themselves. In this way, the craft chocolate company can "inset" its GHG emissions from chocolate production at the Atlanta factory with RECs from solar energy generation in Georgia. These same RECs could be used to inset GHG emissions from the company's distribution activities if an electric car charged with energy from an account participating in the Simple Solar Plan were used for shipment drop offs and wholesale delivery orders. Emissions from shipping are tracked on the Shopify platform and offset by a start-up called Pachama which uses LIDAR to determine biomass density in forests protected by their projects.

The majority of the company's carbon footprint comes from electricity consumption at its factory in Atlanta, and yet to claim carbon neutrality it must also offset GHG emissions from supply chain or upstream activities. Asymmetric information related to offsets can lead to a classic "market for lemons" problem in which the real world GHG reductions of a given initiative are as difficult to predict as the performance of a used car (Akerlof, 1978). To escape this market for lemons, a "former founder" of French, Fair-Trade company Alter Eco started the PUR Projet in 2008 as a social business that uses nature-based solutions to "inset" GHG emissions from agribusiness supply chains (Projet, 2021). Alter Eco, which has its own line of conventional chocolate products, claims to have become a carbon neutral company in 2010 by working with the PUR Projet to offset 100% of its emissions (Eco, 2021). Alter Eco's terminology indicates that the PUR Projet's definition of insets refers to the global supply chain. This craft chocolate company could purchase offsets either from the PUR Projet or an established platform like Bluesource which offers projects based in Georgia at scales appropriate to the limited carbon footprint of a small business.

Given their associative sustainable business models, craft chocolate companies such as the one in Atlanta can also work with cacao cooperatives to identify nature-based solutions from their own supply chains (Gallo, 2018). In 2015, the Tanzanian cacao cooperative Kokoa Kamili hired a “Bwana Shamba” - an agricultural extension field officer who specializes in cocoa agronomy to provide farmers with training in best practices. Since that time, the cooperative has promoted two of its own employees to become field officers with the aim of improving farm yields and bean quality; the craft chocolate company could fund additional training in regenerative agroforestry for such officers and their counterparts at the other cooperatives. Current farming practices amount to agroforestry by default given the use of traditional management techniques. If these traditional management techniques were to be enhanced with formal training in regenerative agroforestry, the craft chocolate company could inset its carbon emissions through more robust sequestration on cacao farms as well as contribute to social and economic sustainability of their supply chains (Haggar, 2017). The organic agroforestry which already characterizes this craft chocolate company’s supply chain can be characterized as a carbon sink (Dawoe, 2016), and it would therefore be advisable for the craft chocolate company to explore the possibility of project development with their own suppliers. Cacao cooperatives generate revenue streams which support organic agroforestry and in so doing they enable small farmers to resist land use alternatives that could lead to deforestation. An offset project could be devised around this business model wherein farmers are rewarded financially for their carbon sequestration. Such a project would enable the craft chocolate company to inset its GHG emissions through verified projects from the company’s own supply chain.

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Discussion and Conclusions

For comparison, industrial chocolate from Northern Italy was found to have more emissions from upstream than core processes despite the inclusion of transportation demands in the latter category (Recanati, 2018). Upstream GHG emissions total 1.55 kg CO_2e, while core processes generate 1.03 kg of emissions for a total of 2.58 kg from industrial chocolate production. These results demonstrate a lower emissions rate derived from economies of scale. By contrast, emissions from the craft chocolate company for the same functional unit (1 kg chocolate with associated packaging) can be as high as 4.26 kg CO_2e in the Tanzanian chocolate case. It is striking that craft chocolate GHG emissions from upstream activities including transportation only range as high as 0.79 kg (Peru) for the same functional unit and thus constitute little more than half the carbon footprint of the industrial chocolate from Northern Italy. Another recent LCA of industrial chocolate estimates the carbon footprint for 1 kg of dried cacao produced with organic agriculture in Ecuador to be 0.47 kg CO_2e, or less than a third of the 1.47 kg GHG attributed to the same functional unit and process at the Peruvian cooperative (Pérez-Neira, 2020). This study demonstrates that craft chocolate makers do not have exclusive access to cacao supply chains with low carbon footprints. Craft chocolate makers can leverage economies of scale to reduce their emissions as well, though further research on a larger enterprise is necessary to determine the extent of such economies. Craft chocolate production could be expected to prove less efficient even at scale given the nature of its production process. The comparison between industrial and craft chocolate implies a false equivalence, however, as they are distinct products. Consumers of craft chocolate who value its flavor attributes do not consider industrial alternatives to be valid substitutes and are therefore unlikely to leave the market for this product even as commercial operations continue to adopt many of the sustainable business practices that originated with artisanal makers (Cadby, 2021). Consumers in the market for artisanal chocolate who value fine flavor profiles but are motivated primarily by the industry’s sustainable business practices, however, and may consequently be lost to commercial competitors who have adopted these practices at lower price points. Artisanal makers can retain this demographic and continue to move the market for chocolate as a whole by making product life cycle assessments standard practice within their industry niche.

As for the ecolabel proposed here, studies indicate that carbon footprint labels must be intuitive to a wide spectrum of consumers if they are to be effective at influencing consumption patterns (Thøgersen & Nielsen, 2016). A specific value for the carbon footprint of a product is meaningless to consumers without sufficient context and can lead to information overload at the point of sale (Meyerding, 2019). With a QR code and statement of carbon neutrality, the craft chocolate company in Atlanta could provide an intuitive signal concerning its product's environmental impact as well as access to the data that underlies this claim. Such quick response access would represent an expansion of the educational role artisanal makers have played in the chocolate industry.

The Atlanta company currently produces approximately 65,000 chocolate bars a year to which 19,175 kg or 19 tons of GHG emissions can be attributed given an average emissions rate of .295 kg CO_2 per bar. Enrollment in Georgia Power's Simple Solar program reduces these emissions by 81 to 86% depending on cacao origin. Thus, the company need only inset 3.6 tons of CO_2e per year to achieve carbon neutrality. This could be done with insets related to the global cacao supply chain from the PUR Projet or with offsets from projects in Georgia available through a platform like Bluesource. For insets from nature-based solutions in their own supply chains, the craft chocolate company can assist cacao cooperatives in the development of offset projects related to the organic agroforestry practiced by their farmers. These organizations are already improving social and economic outcomes for farmers through access to the specialty cacao market; they could generate even more benefits by providing farmers with access to the offset market as well. Various artisanal chocolate makers frequently buy from the same cooperatives and are therefore well positioned to collaborate on such an enterprise.

Limitations and Opportunities for Further Research

A primary limitation of this study is the size of the artisanal chocolate company under consideration. While the company in Atlanta is typical of the small business model which characterizes most artisanal chocolate production, an appealing avenue for future research would be an LCA of craft chocolate produced at scale. It is possible that the craft chocolate from Atlanta would be as efficient as the industrial chocolate from Northern Italy were it to be produced at scale. Another limitation of this LCA is that its system boundaries exclude GHG emissions from the manufacture and maintenance of vehicles and factory infrastructure. Nor does this LCA consider scope 3 emissions related to the disposal of foil and wrappers. The craft chocolate company in Atlanta also produces numerous flavored bars with additional ingredients whose life cycles could be assessed as well. Finally, it is important to note that this LCA does not take into consideration other environmental impacts such as ground and water pollution or changes in biodiversity. This study can be used as a basis for further research into these and other environmental impacts related to the production of craft chocolate.

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