University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
November 2020

Energy Recycling & Craft Beer: Limits & Prosperity

Chad Hartless
Environmental Studies
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dee Eggers

Abstract

Over the last few decades, it has become apparent that modern industrial practices are wreaking havoc on the natural systems which provide for all of life on earth. Realizations that finite resources are being depleted quicker than they can be replaced have brought mounting social pressure on corporations to reconfigure what defines "business as usual". If productivity and profits are to be enjoyed by future generations, corporations will need to replace their current practices with more sustainable alternatives. This can be achieved if industry leaders learn to mimic the cyclical processes of the natural world. In nature, any output from one system is an input for another. Waste does not exist naturally. The concept of industrial ecology seeks to illustrate how industries can rebalance their spreadsheets to include natural capital, and yield greater profits for generations to come, thus repairing the broken relationship between business and the natural world. The tenets of industrial ecology have drawn attention from industry leaders that are eager to reap profits without compromising the well-being of their future stakeholders. Within the craft beer industry, innovators have been trailblazing new ways of doing business that align with these goals. By examining several cases in which productive norms are being redefined, this research seeks to provide lessons and examples for restructuring our economy to work in equilibrium with the environment.

1. Introduction: The Brewing Process & Ethical Business Practices

1.1 The Brewing Process

Fermented grain beverages have long been of interest to homo sapiens with recorded evidence reaching back to 6,000BC.[1] Brewing beer is reasonably simple. Until the modernization of industrial approaches to brewing, beer styles and flavors were mostly dependent on the regions they came from. This was mostly due to wild yeasts in the air. With modern scientific practices brewers can mimic naturally occurring conditions and create any style of beer they'd like regardless of their geographical location. Brewing begins with malting, the process of soaking and drying grains. Barley is the most common grain used in modern brewing, but it is not the only one. Examples of alternatives include rye, wheat and oats. Through different meticulous approaches, different malts are crafted for specific styles of beer. Most breweries do not actually harvest malt themselves. A majority of malt is produced by companies that primarily focus on the production of various malt styles to be sold and shipped to breweries. Once the brewers have their malt, they add grain adjuncts and polymerize the mixture. Liquor is created through the manipulation of pH and salt levels of water, which is then mixed with the mashed concoction, commonly referred to as grist.[2] While inside the mashing vessel the product is kept at precise temperatures. In this stage, one small mistake can mean an entire batch of product is completely ruined. Once the mashing stage has been completed, the wort (liquid) is extracted and boiled with hops. This part of the process is primarily for stabilizing flavor.[3] Fermentation of yeast in the cooled wort is the next step. Different strains of yeast have characteristic flavor profiles that are important for specific styles of beer. Flavor is not the only goal of fermentation; it is at this point that ethanol and CO_2 are spawned within the brew. Maturation is the

next and final step of this rigorous process. Maturation is often viewed as a continuation of the fermentation process and is when the qualities of a beer ultimately settle.

It is necessary for the purposes of this research paper to note the subsequent outputs from this process. Referring to the above explanation of basic brewing methods, it can be deduced that there is waste from the malting process, the filtering of hops, residual yeast, and then (after consumption) the empty vessel which contained the malted beverage. It can also be noted that several steps of this process produce thermal waste as well. These seemingly inherent waste productions are not unavoidable, and the craft beer industry has taken on the problem of dealing with waste in a variety of innovative fashions that will be exemplified further on in this research document.

1.2 The Ethical Business

Corporate Social Responsibility (CSR) is a term commonly used in reference to businesses that engage in ethical practices to further society's well-being. This topic is largely discussed in the context of sustainability efforts, although it can also refer to other forms of philanthropy and activism. For the purposes of this research, it will be discussed in the context of sustainable business practices. The normative case for CSR proposes that firms ought to behave in more socially responsible ways because it is morally correct to do so.[4] However, many businesses have (in the last few decades) begun to realize that there is another case for acting in such a manner: strategic investment. This is epitomized in the craft brewing industry, wherein there are many examples of companies that adhere to these standards successfully. By dramatically increasing the productivity of natural resources there is ample opportunity for companies to solve certain environmental problems at a profit.[5] By improving specific steps in production processes, firms have the potential to increase productivity, while reducing surplus costs, therefore supplementing costs associated with other sustainability upgrades - a standard that breweries like Sierra Nevada have modeled is both plausible and possible (discussed in section 3). This precedent demonstrates ways to make sustainability upgrades far less impractical from a monetary standpoint, providing more opportunity to meet the needs of direct and indirect stakeholders without compromising the ability to provide for future stakeholders as well. The argument that has developed out of this line of thinking is essentially this: it would be short-sighted to focus only on wealth through goods and services provided in the short-term when they compromise future social well-being. CSR is both a moralistic issue and a money issue.

One of the biggest flaws in the current management of business and economics is constraints from the natural environment. Business as usual is unsustainable mainly due to finite resource availability - it does not consider investment in future customers, nor does it consider the costs imposed on nonconsenting third parties in the present. Current systems of production are designed to produce large quantities of consumer goods at a monetary profit. These profits are then unequally distributed amongst a small percentage of wealthy elites. This model distorts the incentives for productivity. Inequitable distributions of wealth lead to the exacerbation of the environment's well-being. Great incentive is given to the wealthiest to degrade the environment. Industries have hesitated (in the past) to invest in more environmentally friendly practices because it was not seen as profitable.[6] However, this is only the case from a short-term perspective. Truthfully, economics as we currently consider it cannot function as a reliable guide unless it accounts for the price of natural capital. With the way current economical practices currently function, there is no way to accurately put a price tag on these lost ecosystem services. For example, the price that is paid by a community when its ecosystems are raided for natural resources are only realized far after the damage has been done. These kinds of oversights lead to many businesses not considering whether the process of creating products is harmful to the environment in their cost/benefit analysis, resulting in skewed conceptualizations of how much profit is derived from these practices. The aggregate waste produced by the modern global economy needs to be considered as the net loss that it is and always has been.

The reason overconsumption has become normalized is a matter of economical deduction. Poverty and environmental degradation have become intertwined in a vicious circle. Environmental degradation benefits the rich and powerful at the expense of others. Poverty is bad for the environment because the poor are less able to resist environmental costs imposed on them by the rich.[7] Those with less resources are typically forced to work within existing systems. In this dynamic, the rich minority reap benefits at the cost of the poorer majority. Environmental degradation is driven at an exponential pace by the poor that are desperately trying to survive within an unsustainable system. Since the poor are receiving pennies on the dollar, the rate of degradation exponentially increases as the poorer class attempts to obtain enough profit to survive. These are all results of perverse incentive systems that have arisen in the absence of successful governance for open-access resources.[8] Without stringent rules and guidelines, like the ones outlined by the tenets of industrial ecology, humans will take advantage of perceived leniency. There will always be bad actors, therefore it is necessary to leave as little ambiguity as possible. Corporate social responsibility was an important mental exercise that did not go far enough to address the negative impacts of big business. It was a stepping-

stone towards a much more comprehensive way of thinking. Industrial ecology is the next step in the evolution of this mindset.

2. Methodology

This research was conducted through a combination of metasearches done on Google Scholar and Jstor, compiled with information retrieved from written journals and books. Metasearches on Google were utilized to find 13 case study examples of breweries implementing sustainable business practices. Through Jstor, one article was accessed that provided information on the brewing process. Written journals and books were referenced to layout the necessary attributes for a sustainable business that would be sought out when finding examples of forward-thinking breweries.

3. Greening the Industry: The Foundation of the Philosophy for Better Business Practices

There are certain norms that will need to be reconsidered for the future of sustainable businesses to flourish. These norms include: humans are dominant as a species and therefore separate from nature; natural resources are inexhaustible; all human needs can be met through material wealth; and individual success is independent of communal success.[9] These ideas are not commonly challenged because for most of humanity's existence there has been no need to do so. While earth's resources have long been viewed as inexhaustible, it has become increasingly evident that this is not the case, yet the desire to consume in most developed and developing countries has seemingly lost no momentum. Demands have exponentially increased as supplies have declined, a trend that classical economic theory would agree is overdue for market correction. Decades of research suggest that integration of both social and environmental aspects are necessary to support sustainable development.[10]

3.1 Industrial Ecology: The Concept

Industrial ecology involves the study of relationships between industrial activities and the environment. The term can (for the purposes of this research) be associated with a conceptual design in which the systems of production ultimately result in no waste creation - similar to naturally occurring cycles in nature, where waste from one process equals food for another, hence the ecological parallel. This way of doing business considers the future adaptability of markets as well as the pressures placed upon living systems by industrial practices. These refined concepts of doing business have the potential to dramatically increase returns for industries while simultaneously lessening their burden on the natural world.

A closed loop system is a system in which every output from one process is an input for another. Closed-loop material flows between extractors, processors and consumers will inevitably reshape business moving forward. The closed-loop concept can be used to analyze products and material flows to improve product-environment interaction. Many craft beer breweries have realized the efficiency of this and have begun incorporating this design into their practices. Analyses of the sorts these brewers are doing eliminates the need for constant extraction of resources to create products because the products are retrofitted to be repurposed. Therefore, there is no longer a need to consider the costs of waste disposal or environmental deterioration because there is no such thing. While this may require innovative rethinking on the part of manufacturers, the result ultimately benefits them as they in turn maximize the productivity of their resources.

3.2 Waste = Food

The processes within nature are cyclical. For example, after an animal eats a plant, it releases any nutrients it does not require in the form of feces, which subsequently nourish another creature, like dung beetles, or flies. The waste of the natural world is not waste at all, it is all food for other organisms.[11] The correlation between rise in waste production and gross domestic product is the crux of humanity's dilemma. This destructive relationship developed because of a lack of accountability placed on businesses to be responsible for their products after they have been sold. If this deleterious rate of waste creation is to be ended, it will be necessary to change the dynamic between business, products, consumers and nature. It is imperative that humanity put an end to the extraction of natural materials for the purpose of creating substances that have no purpose within the natural world. This goal can be realized by creating truly

intelligent systems of production in which every component is designed for easy reuse, remanufacture, reclaiming or repurposing generally as material input.[12] The products that companies release to the public are typically not created with human or ecological health in mind. A simple example that highlights this concept is packaging. Products and packaging should no longer be made of harmful toxic materials, which possess no useful purpose besides the single time they are used - such as plastic or Styrofoam. These products should instead be constructed from materials that can feed microorganisms upon disposal, they should be compostable, biodegradable and nontoxic. Communities should not need to worry about where to place discarded materials that may sit for hundreds, if not thousands of years before degrading even slightly. Bottles, wrappers, containers and all the rest can easily be made to give back nutrients to the soil. There is no need or purpose for waste. This concept can extend to all products that are output by companies, which must be held accountable for their creations not just until they are sold, but for their entire lifespan.

3.3 Providing Ecosystem Services

The mindset of the sustainable businesses will consider the ecological implications of all their practices. When considering ecosystem services, this will mean that businesses consider how they can support and perhaps even augment the ability of local ecosystems to benefit people. This ideology is all encompassing - it is not only the creation of products for sale that will be scrutinized. Location, building design, landscaping, every single component is important. Developing a piece of land should not just mean that it is built upon. The issue with this way of thinking is that it views productivity through a very narrow scope. It is certainly a form of development, but is land better simply because a structure has been built upon it? Productivity and development have been defined under very questionable parameters since the industrial age began. It appears the modern world cannot view nature as being productive unless it has been in some way subjugated by human ingenuity. Although, a piece of land is not made better just because is has been built upon. In fact, human development often inhibits the productivity of nature and is more of a detriment to natural cycles than it could and should be.

Building design that seriously considers environmental impact can be referred to as green building.[13] A truly green building fits into the community and region where it is located, it does not impose. Green buildings do not only aim for minimum impact on ecosystems. They enhance ecosystem services on the site that they were built upon. An ambitious project may even seek to restore a degraded piece of land. These goals can be achieved in a multitude of ways and leave plenty of room for creativity. Some examples include: planting native plants to provide habitat for local fauna; building to consciously avoid soil erosion; choosing a location and design that work together to reduce impact on local ecosystems; or enhancement of air, soil and water quality. Many buildings are considered green based upon only the energy that is technically saved through structural design.[14] However, this is not enough of a consideration. This line of thought leaves ample room for bad actors to declare themselves environmentally conscious if they have considered just a small fraction of the impacts their building will have upon its surroundings - a gross overlook if businesses are to ever tackle sustainability issues truly in good faith.

3.4 Why Being Less Bad is no Good

"The best way to reduce any environmental impact is not to recycle more, but to produce and dispose of less".[15] The path of least resistance may be appealing, but it is often not the most beneficial route to take. According to a survey done by the EPA from 2015-2017, the recovery rate for recycling was a mere 35.2%.[16] Despite decades of public education campaigns and infrastructure building the public still fails to recycle even half of their recyclable goods. Imagine now, if all that effort and education outreach had been put into solving the problem of waste instead of trying to mitigate it slightly. This example illustrates why half measures are not enough, it does not suffice to simply be less bad. The Ellen MacArthur Foundation's study on plastics in oceans found that if we continue our rate of plastic usage, then by 2025 there will be one ton of plastic in the ocean for every three tons of fish.[17] While not all that plastic was necessarily recyclable, the implications are still undeniable, the half-measures people often choose to take are not enough. Perverse permission structures have allowed people to continue using harmful materials while believing they are safe when it is factually incorrect. Another easily digestible example is the idea of a building (from section 2.3) being considered sustainable because it is more energy efficient. A building under this loose definition of sustainability could have been built upon important habitat, in the middle of nowhere, requiring its employees to drive long distances, emitting greenhouse gases every day to get to their place of work. That is not truly sustainable, it's only less bad, and less bad is not good enough.

4. Applications of Concepts: What Does it Look Like to be Better?

Human prosperity is in danger of being overcome by waste that is output by current industrial practices. In the U.S., forward-thinking breweries have begun to adopt the concepts of industrial ecology, shifting their focus to reducing waste, while cultivating more sustainable practices in the workplace. Some of these new methods will be observed in the second section of this research paper, which seeks to provide examples of sustainable business methods put into practice.

4.1 Closing Loops: Examples of Applied Industrial Ecology

Sierra Nevada Brewing Co. is a leader of the brewing industry's growing sustainability movement. One practice they have implemented at both of their main brew operations (one in California and the other in North Carolina) is the capturing of CO_2 output naturally during the fermentation process of brewing for reuse.[18] Sierra Nevada cleans this captured CO_2 and uses it to pressurize tanks as well as carbonate to-go beer. This means that they do not have to buy CO_2 from other companies or pay for it to be shipped to them. This innovation decreased their reliance on delivery trucks, which output greenhouse gases in transit, and saved the company just under half a million dollars per year that would otherwise have been spent needlessly on a product they were already producing themselves. Furthermore, since Sierra Nevada began this practice, they have seen a 56% reduction in their overall greenhouse gas emissions. This is an example of an applied closed-loop system, an important concept for sustainable business efforts going forward.[19]

Sierra Nevada repurposed their "waste" from one step in the brewing process and made it profitable. One of the most common sources of waste across all industries tends to be thermal energy. This is because the most common output in any energy system is heat.[20] The process of brewing is no exception. The second law of thermodynamics clarifies that in any thermodynamic process energy will escape, this is referred to as entropy. Therefore, it can be said that while energy and matter will never cease to exist, the monetary value ascribed to them can in fact diminish. CO_2 output during the fermentation process could simply be released into the atmosphere, but a more intelligent system repurposes it for carbonization. This cyclical pattern can be observed everywhere in the natural world, the earth is itself a network of closed-loop systems. Every output from one process is an input for another. This brilliant efficiency is the goal of the evolutionary corporation.

Heat produced from energy transformation can be captured and harnessed for other steps of the brewing process. The Steinecker EquiTherm Brew is a state-of-the-art heat recovery system that captures heat output during the cooling of wort and reuses it throughout the entire mashing process. This provides a twofold sustainability increase. First, primary energy only needs to be input during wort boiling. Second, excess hot water production which is typical of this stage in the brewing process is avoided.[21] This system provides a 40% reduction in electricity costs and provides savings equal to the initial cost of the system within a 1.5-year period. Furthermore, it increases thermal energy productivity by 55% while simultaneously reducing thermal peak load by 50%. This system is designed to be integrated into modern breweries and allows for upgrades. In fact, this is just one part of a much larger conceptual brewing system that is entitled Brewnomic.

The Brewnomic brew system is by far the most comprehensive closed-loop system that can be bought and installed for large-scale brewing operations. The system's foundation is the EquiTherm Brew heat-recovery system. This system can be purchased separately, thus allowing breweries to work their way up to producing all of their power within their own domain and achieving carbon neutral productivity. With the installation of the full Brewnomic system, residual materials that contain high energetic potential are fermented into methane that can be used as a potent energy source.[22] The biogas boiler is also utilized in tandem with the EquiTherm as part of a combined heat system. The system is also retrofitted so that a brewery with solar panels can store cold energy obtained from photovoltaic cells in fermenting tanks. The culmination of all this technology has the potential to produce up to 10% energy excess, which can then be sold or given back to the power grid.

Similar systems that use reclaimed steam have been implemented at the Brooklyn Brewery in New York, NY. Since 2013 reclaimed steam has been used to heat hot water heaters as well as to sanitize bottles on their bottling line, eliminating the need for chemical cleaners while reducing energy costs.[23] Kona Brewing Co. in Hawaii is currently constructing an on-site wastewater treatment facility (very similar to the treatment facility that Sierra Nevada's Mills River location has). Inside this facility, captured methane will be turned into electrical energy with anaerobic digestors, thus repurposing extremely potent waste as a useful source of energy.[24] In each of these examples, energy was being released regardless of the step in the production process. All that changed was the capacity of these businesses to maximize the productivity of their resources. These are the kinds of changes in approach that will catalyze the

evolution of sustainable corporate practices. The main challenge is the availability of existing technologies that can turn these linear production systems into closed loops.

4.2 Using Less = Having More: Examples of Waste as Food

Not all production processes can become closed-loop systems in which energy or matter is used in another step later. Certain byproducts have little realistic applicability for such specialized industries with current available technological capacity. However, this does not mean that the conclusion is one in which these byproducts are wasted. Allagash Brewing Company is one of many breweries that saves their spent grains to be picked up by farmers.[25] The nutrient rich grains are excellent feed for cattle and livestock, putting this energy back into the larger system in the form of nourishment for other living organisms. A similar approach can be observed at Sierra Nevada Brewing Co., where all their food scraps (from their restaurant) are composted and used to create biogases that supplement fuel for their delivery trucks. Anderson Valley Brewing Company treats 100% of their wastewater on-site and then uses it to irrigate their goat pastures and hop fields.[26] They also feed their spent grain to local cows and use their spent hops as natural fertilizers. Hops & Grain Brewing in Austin, Texas uses their spent grain to create their own Brew Biscuit dog treats - an inventive way to not only avoid extra waste, but also further increase profits without too much extra effort.[27] Saltwater Brewery was the first brewery to implement Eco six pack rings when they became aware of the devastating impact plastic six pack rings were having on marine life.[28] Many marine organisms find themselves entangled in the plastic rings, resulting in death due to suffocation. Upon discarding, the Eco six pack rings decompose within a matter of weeks, as opposed to plastic rings which can take centuries to degrade. The rings are also safe to be consumed, although they do not seem to provide any significant nutrients upon digestion.

4.3 How to: Provide Ecosystem Services

In 3.1 and 3.2, breweries were mostly able to maximize the productivity of their resources for a monetary profit. However, the value of natural capital has not been defined or ascribed under the common economic paradigm. This does not mean that natural capital is without value, for all life on earth relies on natural systems to exist. The knowledge of this fact has led to many brewers finding new ways they can give back to the earth, providing optimal conditions for life to thrive with their brewing methods.

The Brewnomic system discussed in section 2.1 has a few more significant advantages to it that are more appropriately discussed in this section of the paper. These advantages have to do with the creation of biogas (a combination of methane and carbon dioxide). Biogas provides unique opportunities for breweries to purify water, enhance soil quality and provide habitat. Biogas does not require extra energy to be made, and in the process of making it, there are certain pathogenic microbes and parasites that are deactivated, creating potentially cleaner water for people, plants and animals.[29] The byproducts from biogas creation are enriched organics (compost) that can be used as natural fertilizers to stimulate plant growth and enhance habitat for native animals.

An excellent way to provide habitat for local fauna is by implementing natural landscaping. When Sierra Nevada purchased their second location in Mills River, North Carolina they were excited to make use of the large expanse of forest on their property. They quickly realized, that much of the forest was taken over by exotic-invasive species which were diminishing the overall health of the forest. Since their arrival, they have hired natural resource specialists that to remove these invasive species and replace them with native species that can provide habitat for native wildlife.[30] Their Mills River location is the first brewery to receive the Audubon Cooperative Sanctuary award for their native-friendly plant species, water efficient landscaping, and array of bat/bird boxes built to provide extra shelter for fauna.

New Belgium's third brewing location in Asheville, NC is made of entirely reclaimed wood and was purposefully built on a Brownfield's site.[31] The project developers chose to plant native pollinator friendly plants to rejuvenate local bee populations, and in the interest of providing as much habitat as possible, the brewery was built around a degraded stream. Since their arrival, the streambank has been remediated with native plants. The stream channel itself has also been revitalized with rock structures that stabilize beds and banks while simultaneously providing habitat. Lost Coast Brewery is another brewery that incorporates native plants into their landscaping model. They foster over an acre of plants that are native to the California Floristic Province in their Humboldt Botanical Garden. Their botanical garden is not only great for the local wildlife, it also provides space for educational opportunities for children that are curious to learn about their state's native plants.[32]

5. Conclusion

The concept of waste is a foolish invention that belongs to humanity and humanity alone, it has no place within the natural world and must be redefined as what it is - a system input. In order reconcile with this realization, businesses will have to fundamentally redesign their practices and align them with the cyclical processes of nature. If big businesses desire to survive the oncoming centuries, or even decades, it will be necessary for sustainability to become the fundamental preliminary consideration before any final decisions. This can be accomplished through the redefining of norms and enhanced understanding of ecological costs associated with doing business. This research has provided ample evidence of a complex industry successfully implementing the tenets of industrial ecology through various approaches. Research of this nature exemplifies that any industry can change to be more sustainable, it just requires some innovation, even if it's just one step at a time.

6. References

1. John McCabe, *The Practical Brewer: A Manual for the Brewing Industry* (American Association of Cereal Chemists, 1999), 1:100.
2. Thomas, Keith. "Beer: How it's Made - The Basics of Brewing." *Liquid Bread: Beer and Brewing in Cross-Cultural Perspective*, edited by Schiefenhavel Wulf and Macbeth Helen, 35-46. Berghahn Books, 2011. Accessed August 25, 2020. http://www.jstor.org/stable/j.ctt9qd5gz.10.
3. Chris Cohen, "Study Guide for the Certified Beer Server Exam " (The Beer Scholar, 2015).
4. Branco, M. C., & Rodrigues, L. L. (2006). Corporate social responsibility and resource-based perspectives. *Journal of Business Ethics, 69*(2), 111–132.
5. Ray Anderson, Speech given at the Plenary Lecture at the 3rd National Conference on Science, Policy and the Environment: "Education for a Sustainable and Secure Future" January 31rst, 2003.
6. Ellis Jones, "Brewing Green: Sustainability in the Craft Beer Movement" *Craft Beverages and Tourism*, Vol. 2 (2018): 1-13.
7. James K. Boyce, *The Political Economy of the Environment* (Edward Elger Publishing Limited, 2002), 5, 44.
8. Deitz, 2003
9. Anthony D. Coretese, "The Critical Role of Higher Education in Creating a Sustainable Future", *Planning for Higher Education*, Vol. 31, No. 3 (2003): 15-22.
10. Guerrero, Angela M, Nathan J Bennett, Kerrie A Wilson, Neil Carter, David Gill, Morena Mills, Christopher D Ives, Matthew J Selinske, Cecilia Larrosa, Sarah Bekessy, Fraser A Januchowski-Hartley, Henry Travers, Carina A Wyborn, and Ana Nuno. "Achieving the Promise of Integration in Social-ecological Research: A Review and Prospectus." *Ecology and Society* 23, no. 3 (2018). Accessed November 4, 2020. doi:10.2307/26799168.
11. William McDonough and M. Braungart, *Cradle to Cradle* (North Point Press, 2002), 45, 117.
12. Paul Hawken, *The Ecology of Commerce: A Declaration of Sustainability* (HarperCollins Publishers, 1993), 68.
13. Deni Greene "Consulting Services for the Task Force on Sustainable Development" The Institution of Engineers, Australia. "Green Building." *Environment Design Guide*, 2005, 1-3. Accessed November 4, 2020.
14. Pollard, Trip. "Building Greener Communities: Smarter Growth and Green Building." *Virginia Environmental Law Journal* 27, no. 2 (2009): 125-46. Accessed November 4, 2020.
15. Robert Lilienfield and W. Rathje, "Use Less Stuff: Environmental Solutions for Who We Really Are" (Ballantine Books, 1998).
16. U.S. Environmental Protection Agency, "Facts and Figures About Materials Waste and Recycling/National Overview Facts and Figures Materials", EPA.gov, http://www.epa.gov/
17. TEDx Talks, "A Radical Plan to End Plastic Waste", Ted.com, https://www.ted.com/
18. Sierra Nevada Brewing Co., "Chico Sustainability Map", Sierranevada.com, https://www.sierranevada.com/
19. Marion Gilson and Paul Van Den Hof, "Instrumental Variable Methods for Closed-Loop System Identification." *Automatica*, Vol. 41, No. 2 (2005): 241-249
20. Gilbert, Kirss, and Natalie Foster, *Chemistry: An Atoms-Focused Approach* (W.W. Norton & Company, 2014), 362.
21. Krones, "Recycling Thermal Energy During the Brewing Process", Krones.com, https://www.krones.com/
22. Krones, "Steinecker Brewnomic", Krones.com, https://www.krones.com/

23. Brooklyn Brewery, "Sustainability", Brooklynbrewery.com, https://www.brooklynbrewery.com/
24. Kona Brewing Co., "What's New - Sustainability", Konabrewing.com, https://www.konabrewing.com/
25. Allagash Brewing Company, "Sustainability", Allagash.com, https://www.allagash.com/
26. Anderson Valley Brewing, "About Us", Avbc.com, https://www.avbc.com/
27. Hops & Grain Brewing, "Brewing Sustainability", Hopsandgrain.com, https://www.hopsandgrain.com/
28. Saltwater Brewery, "Community - Eco Six Pack Rings", Saltwaterbrewery.com, https://www.saltwaterbrewing.com/
29. National Center for Biotechnology Information, "Elsevier Public Health Emergency Collection", https://www.ncbi.mln.nih.gov/
30. Sierra Nevada Brewing Co., "Mills River Sustainability Map", Sierranevada.com, https://www.sierranevada.com/
31. New Belgium, "New Belgium: A Behind the Scene Look at Making a Sustainable Site for the Brewery", Greenbuilt.org, https://www.greenbuilt.org/
32. Humboldt Botanical Garden, "Lost Coast Brewery Native Plant Garden", Hbgf.org, https://www.hbdf.org/