Ceramics & Alternative Energy Sources

Environmental Science and Sustainability

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Abstract:

The brick and tile industry is a substantial contributor to the global greenhouse gas emissions and a partial contributor to the planet's current global climate crisis. This project will examine the issues of the brick and tile industry and explore possible solutions. This approach will examine the corporate brick industry, and apply holistic sustainable practices to that industry through a reimagining of standard processes within the recreational pottery industry. Specifically this paper will examine the use of alternative fuels as well as consciously harvested materials. These sustainable practices include the utilization of waste vegetable oil (WVO) and locally harvested clay. This paper will explore the utilization of the alternative fuel (WVO) as a viable option for firing ceramic objects. Through that lens the paper will generate suggestions suitable for the large-scale brick and tile industries.

Chapter 1: Introduction

The purpose of this project is to examine the environmental effects of the industrial ceramic brick and tile industry, and apply the theory of holistic sustainability in order to discover solutions to aid in suppressing our world's current environmental crisis.

In environmental practices, the term sustainability has become a defining and guiding term for conservationists and environmentally minded individuals. Sustainability is often thought of as an ultimatum, an irreversible transition, in that humans must make massive sacrifices in their lives - leaving behind a former lifestyle for a changed one.

These sacrifices, or changes, may be minimal: fewer plastic straws, eating less meat or even as much as composting your leftover fruits and vegetables. These changes (in some places, movements) have slowly been growing in popularity around the world. There seems to be, what might be framed as, last-ditch efforts in changing the social norms to include environmentally sound practices and thereby, possibly, avoiding a collapse of the entire system. Let's be clear that not one single change will cause a systemic, comprehensive and global reversal of our larger environmental problems. However, some of these changes might help the plight if but by a degree.

Sustainability is defined as meeting our own needs without compromising future generations from meeting their own respective goals (University Of Alberta, N.D.); This loose definition quickly evolves into and touches the topic of sustainability: how to become sustainable and use sustainability as a manageable goal for all participants. Trying to achieve "perfect sustainability" seems almost perfectly impossible; only those individuals who have the privilege to do so (economic, social, etc.) are able to drop and/or manipulate their routines in order to stay on track with the goals of sustainability (United Nations, 2023). As we progress towards the future, these goals such as affordable and clean energy, sustainable development and industry, innovation and infrastructure become increasingly more important. This need for and desire to create a sustainable culture is not the only modern goal currently under review. We also have a parallel goal to keep our social and interconnected society. We must lay a foundation for these

two simultaneous goals (let alone other commensurate goals) and commit ourselves to them as this is the change needed to ensure the safety and security (in some small way) of the species.

Keeping in mind the multi-layered (and multi-defined) goals of sustainability, as well as the loose definitions that they require, the topic of technological innovation should next be addressed. Stasis is not necessarily a comfortable part of human nature; however, expansion and innovation ARE well-understood facets of the human experience. To that end, resource extraction almost becomes unavoidable. Almost every tool of technology we have today correlates with some type of removal and manipulation of Earth's resources: solid, liquid and gas. In many senses, sustainability is often seen as oppositional to our own growth and development as a species. Simply put, if we stopped progressing the Earth, as an ecosystem, would benefit.

Although the two points, development and sustainability, seem to be at odds with each other, the two do not need to be separate entities; arguably, they can co-exist. As the definition states, sustainability must allow us to meet our own needs as well as ensuring a quality future for generations to come. This can be done by viewing sustainability within a range, a spectrum. This spectrum includes the many sustainable goals including development, architecture, food and water quality and responsible consumption practices. While aligning the goals of sustainability within a spectrum, developmental goals seem much more achievable rather than ultimatums which can be imposed on individuals or groups of people. By changing our everyday recreational practices, we are given the opportunity to remove ourselves from supply chains, break-off from traditional developmental goals and provide new avenues for sustainable progress.

Breaking traditional supply chains and favoring more environmentally sound practices is not as easy as it sounds. There are a multitude of factors which must be accounted for when breaking up a particular supply chain. For example, and the main idea for the remainder of this discussion, the ceramic brick and tile industry fits into an interesting historical and contemporary world context. Bricks have been noted as one of the greatest and most useful inventions of humankind, serving as an important milestone for humanity (Chudley, 2000). Ceramic bricks made from clay have existed for thousands of years. The reason for their massive influence on the world comes from their insulating capabilities as well as their architectural possibilities (Chudley, 2000). Accounting for 50% of the total ceramic industry, bricks and tiles have become one of the most common and reliable building materials across the world. On an industrial scale,

ceramic bricks are fired in mass amounts using natural fossil-fuel gasses (Shakir *et. al*., 2013). These bricks are fired to a temperature of around 800-1300°C, which requires a substantial amount of power to be able run for a firing interval (Furszyfer Del Rio, et al, 2022). Additionally, bricks produced had an average fuel consumption of 1.8 MJ/kg of bricks produced. Individual industrial brick kiln's fuel consumption varies from 100 - 300 kg of coal per 1000 bricks (Nairobi, 1991). Consequently, the industrial ceramic industry is responsible for a significant portion of the total carbon emissions released on a yearly basis. Globally, the brick industry alone is responsible for 2.7% of total carbon emissions emitted into the atmosphere each year (Rauniyar, 2019). The emissions released range from carbon dioxide, nitrous oxide, water, sound and air particulate. With the growing demand for ceramic bricks and tiles, these pollutants seem almost unavoidable. The brick and tile industry has the world and its resources locked up (Ganesh *et. al*., 2020).

As the reliance on the ceramic industry remains constant, a steady expenditure of energy is necessary to maintain current brick and tile production quotas. Emitting carbon dioxide into the atmosphere, natural gas is the main source of fuel that is used in this massive industry (Boschi *et. al.*, 2020). There are a plethora of replacements for the natural gas fuel source including: electricity, wood and even biofuels. The goal is to find an energy source with a high energy potential and one that, simultaneously, has low pollutant emission rates.

Electric powered kilns are quite common. Ceramic soft brick is inlaid within the kiln, and metal coils called elements line the inside of the brick. Inside the kiln, elements heat and incubate the controlled center, opening a space for clay vessels to be turned into ceramic. Electric kilns can be incrementally controlled to a multitude of temperatures and set to timers to get an accurate and consistent result for their ceramic products (Zakin, *et. al.*, 2015). If applied to the ceramic industry, specifically in bricks and tiles, electricity and electric kilns would not be able to produce the bricks efficiently. A study conducted by *C. Ronneau (2004)* found the energy potentials of various fuel sources. Energy potential is defined as the amount of energy that can be released based on the mass of an object. Electricity contains a very low energy potential, so the amount of electricity needed to fire bricks on an industrial scale would be large (Ronneau, 2004).

An alternative fuel that could be used to fire bricks is a separate class: wood. This natural material is a renewable resource which contains a slightly larger energy potential than electricity, and has remained a tried and true source of energy for millenia (Ronneau, 2004). However, the

brick industry cannot rely on a material like wood to power its production. Albeit a renewable resource, the use of wood to fire bricks would not be feasible. The energy required would necessitate a massive amount of wood, which would require a large scale deforestation to provide our world with its necessary bricks. For example, the brick industry in Sudan possesses a larger part of firing which relies on wood;. The result is mass deforestation (Syed Asharaful Alam, 2009). The effects of deforestation are vast including erosion, droughts and the weakening of air quality (Chakravarty, Sumit, et al., 2012). Therefore, using wood as a substitute for natural gas during brick firings would be counterproductive.

Another sustainable alternative to wood, electricity and fossil-fuels for industrial brick firings is the use of chemically produced biofuels, which are derived from animal fats, plants and feedstocks. Commonly used materials in the process include soybean oil, corn oil and even waste vegetable oil (WVO). The process of taking feedstocks and animal fats and processing them into fuel is made possible through a process called transesterification. This process involves the use of ethanol and methanol, separating out methyl esters (the replacement fuel for petroleum based products) (Knothe, 2015).

The popularity of biodiesel has arisen for several reasons, the first being its heating potential compared to its competitors (Knothe, 2015). D'Alessandro *et. al*., displayed this in their study, where a collection of fuel sources were collected and spent in a combustion engine. Each oil's energy capacity was measured (the physical amount of energy within an object's given mass), as well as their carbon oxide and nitrous oxide emissions. The study displayed the standard diesel fuel to have a similar energy output as biodiesel, while using significantly less diesel fuel (D'Alessandro *et. al*. 2016). However, the emissions for biodiesel are significantly lower. In this same experiment, biodiesel was shown to emit significantly less carbons into the atmosphere compared to diesel fuel within the combustion engine (D'Alessandro *et. al*. 2016).

The brick and tile industry is a large contributor to global GHG levels; That stated, the industry should consider an alternative method of energy consumption. Natural gas and other petroleum based fuels may have a high energy capacity, but their emissions are too great to ignore. Biodsiel however contains these sustainable attributes while having a larger energy potential than, lets say, a natural resource like wood. In a study completed by Hore-Lacy (2011), the energy density and energy potential of a few materials were compared. Biodiesel's energy density, or the amount of energy that is contained within the materials mass, is shown to be larger

than coal and wood. Biodiesel's energy density simultaneously falls short of the petroleum based fuels: gasoline and diesel fuel (HorelLacy, 2011; Pimentel, 1991). Biodiesel is also biodegradable, so the risk of contamination through spills or leaks can be reduced (Bowman, *et. al*., 2006). By switching to biodiesel instead of the current use of natural gas, the brick and tile industry would be able to significantly lower global GHG's, as well as a significant drop in particulate matter pollution.

However, Biodiesel is NOT a magic bullet. Biodiesel comes with disadvantages like its high chemical input and manufacturing process, but as it is derived from abundant natural resources as well as recycled materials, biodiesel would provide a great alternative to natural gas (Capuano, 2017).

For this project's purpose, the utilization of biodiesel for small scale kiln firing would not be sustainable. The transesterification process requires a significant energy input, and requires the use of water, methanol, ethanol and several other chemicals (listed below). In this case study, B. Esteban, *et al.* looked at the entire life cycle of vegetable oil that underwent the biodiesel production process. The biodiesel from vegetable oil was found to be less sustainably advantageous, as the energy and material input of the biodiesel process was high. Although the emissions of burning straight vegetable oil was higher than the combustion biodiesel, the energy put into creating the biodiesel ends up being a greater investment for producers (B. Esteban, *et al.* 2011). By basing on both price, time, energy and material, a small-scale potter would not benefit from using biodiesel as a source of energy. Additionally, waste oil (WVO) must undergo a significant pre-treatment before the transesterification process can begin because of its greater potential for impurities, adding to its energy investment (Araújo, 2013). Waste vegetable oil (WVO) can be considered a viable option for this project; WVO is a common material, and outside of cooking and biochemical production, it has very limited uses. The energy potential of WVO compared to chemically treated biodiesel is almost on par, with treated biodiesel ranked slightly higher in energy capacity (D'Alessandro *et. al*. 2016). CO emissions of WVO are also displayed to be higher than both diesel fuel and biodiesel; standard diesel fuel emits roughly 125-150 PPM of CO emissions, compared to WVO's roughly 150-160 PPM (D'Alessandro *et. al*. 2016). Although the emissions of the combustion of WVO is higher than petroleum based fuels, WVO is still a viable material for experimental and recreational potters. This is derived

from using WVO as a source of energy and providing an extension of the waste oil's life cycle (Chhetri, 2008).

These holistic practices will take the form of utilizing carefully harvested resources and recycled or spent materials. The demonstration will involve taking industrial ceramic practices and providing an alternative energy source to commonly used fossil-fuels. Similarly, this exercise will involve utilizing the abundant and commonly recyclable material WVO, and using it to fire a small recreational kiln containing traditional ceramic pottery.

Holistic sustainability is again looking at the broader functions or layers of the world, that being the global economy, our population, our physical environment and the governance or legislation which provides our framework (Sachs, 2015). Sustainability under this broader point of view allows for us to keep developing and advancing our species, while not having to make life altering sacrifices. This ensures we can keep our daily wants and needs part of our lives. Sustainability is not an ultimatum, but rather a conscious spectrum which we must align ourselves on and have a level of awareness towards not only our Earth, but our social, economic and political systems as well. Holistic sustainability can be achieved in numerous ways; the intention of this project is to replace the commonly used energy source (fossil fuels) and replace it with the abundant material, waste vegetable oil (WVO).

The purpose of this project is to examine the environmental effects of the industrial ceramic brick and tile industry and apply aspects of holistic sustainability to members of the smaller ceramics community who do not work at an industrial scale. To do this, the industrial ceramic practice will be reviewed. Then the conclusions drawn from this review will be superimposed on small scale, or recreational pottery. By reviewing the practices of small-scale pottery and viewing it through a similar lens generally focused on the industrial ceramic industry, the implementation of sustainable practices will be much easier to apply. These different arms of the same industry will allow the larger ceramic industry to consider newer, more sustainable practices in order to align itself with our broader goals of sustainability currently in use in other industries around the world .

Chapter 2: Literature Review

The Future of Holistic Sustainability

The term sustainability has become quite powerful and omnipresent in media and the current culture. Our goal as a society has slowly transformed as of late, now becoming a push for more sustainable means and sustainable lives. Many things in our way of life might change, as we gear up for humanity's next revolution. To demonstrate these changes, history is an excellent guide. Our previous industrial revolution saw a rapid growth for humanity. Through fossil-fuels, our lives were quickly made easier. However, fossil fuels eventually contributed to a downward trend in our quality of life as the generated pollutants when combusted has increased overall pollution levels in our world. New thinking has created a method in which we can now begin to think about the sustainability of the planet's (and its inhabitants) future; we must continue to advance while securing the future for the next generations. Sustainability began as a movement to conserve resources. Currently, sustainability takes a more nuanced viewpoint: to be sustainable, a more holistic approach is more useful. A point of view whereby knee-jerk responses to issues must be tempered by considering a wider availability of opinions. In other words: to get input from all concerned parties. By concerning sustainability on a spectrum rather than an ultimatum and taking a wider approach, humans can opt for various and multiple strategies especially in energy consumption.

The opportunity now exists to break out of existing supply chains, reuse materials to extend their life cycles and develop our own sustainable practices. By using the concepts of sustainability, we are less likely to have to mandate draconian changes to the culture. Sustainability *should be* through a spectrum rather than an ultimatum. Taking a broader, thoughtful and inclusive approach, we are capable of achieving our goals while safely securing the future generations.

Sustainability, in modern usage and parlance, has become synonymous with a more secure future and a positive attainment of goals. As defined, sustainability means the rights to secure our wants and needs without compromising the lives of future generations (University Of

Alberta, N.D.). Essentially the current generation needs to ensure that future generations have the same, if not better, access to opportunities. However, global trends have indicated that future generations may have already been compromised. Globally, greenhouse gasses have been on a steady rise for the last 100 years of industry's growth and development. Due to this exponential growth in industry, the subsequent emissions also have been on the rise. Fossil-fuels alone account for roughly 75% of total greenhouse gas emissions. Global carbon emissions have built up over time, totalling roughly 10 Billion metric tonnes of Carbon that has been released and polluted into our atmosphere (Boden, 2017). Additionally, the overconsumption of fossil-fuels and greenhouse gas levels has propelled the global temperature to rise by (+.14℉) per decade since the year 1880. Additionally, since 1981 the rise has more than doubled at (+.32℉) per decade (NOAI, 2020). This may not seem like a drastic increase, but the compounding effects of warming have begun to melt ice caps and permafrost. As the ice melts, sea levels will rise. This leads to the increase in severe weather events (Thibault, 2008). The more fossil-fuel energy that is expended, the more the Earth will warm: fossil-fuels have the world trapped in a positive feedback loop, trapped within itself and constantly adding to the problem.

To break this loop and ensure the success of future generations, as mentioned above, sustainable measures need to be implemented. The term "sustainability" has been part of the environmental vocabulary for quite some time. Original definitions of the term called for the conservation and preservation of our natural resources. As far back at the 1980s, at The World's Conservation Strategy, Author Lee Talbot stated: "human beings, in their quest for economic development and enjoyment of the riches of nature, must come to terms with the reality of resource limitation and the carrying capacity of ecosystems, and must take account of the needs of future generations (Talbot, 1980)." Ecosystems, in fact, do have limited resources. However, it has been argued that full conservation of resources inhibits people from their rights as humans. This argument seems limited in logic; if non-renewable resources are used to their extinction, are human rights not violated then and there as well? Again, sustainability is defined as securing not only the future generations wants and needs, but ours as well. Older generations looked at sustainability as an ultimatum, but this oftentimes is viewed as denying our generation from progressing further. To achieve a sustainable future, this definition must evolve. Its flexibility must match the circumstances.

New definitions of the term sustainability have allowed for more opportunities while thinking in an environmentally conscious mindset. Economist and environmental development advisor Jeffery Sachs has an interesting viewpoint when it comes to sustainability. Sach stresses the importance of taking a holistic approach when it comes to writing the rules of sustainability. Sustainable development is described by Sachs as multiple complex systems working in unison to achieve a goal, that being securing ours and future generations' success and welfare. These systems are composed of four parts: the world economy, the global society, the Earth's physical environment and a solid governance system to provide a framework (Sachs, 2015). This takes the normal conversation of "we need to conserve resources," and more or less flips it into a different perspective. Conserving resources of course aligns with sustainable development, but it fails to include many important aspects. Sachs instead takes a more holistic approach, thinking about the broader issues. Sustainability cannot be forced; Rather, sustainability needs to be achieved through socialization. This sustainable socialization will still allow economies to flourish while preserving our Earth's physical nature. All of this can be made possible by a solid governance to provide a framework. These systems are complex, and to get four at once to work in unison may be difficult. But when your governance can start by changing the social nature of your society, sustainability will slowly but surely be achieved.

To writers like Sachs, sustainability cannot be fit inbetwixt our complex systems that run humanity. Consider for a moment the global economy. Without our global economy, humanity may simply lose its ability to function. To Sachs, the culture of sustainability needs to be implemented from the ground up, and sustainable practices must be socialized into our society. Socializing sustainable practices is incredibly important to not only preserving the Earth's ecosystems, but keeping our economic systems flourishing as well. Sustainability and the preservation of economies, in Sach's argument, are interlinked goals. Sustainable practices can slowly be socialized into our society. A large part of that can be achieved through consciously taking steps to ensure goals are met but the steps to achieve these goals must be done so safely. Examples of sustainable changes are (but not limited to) using alternative sources of energy, breaking out of common supply chains and utilizing materials past their intended (or defined) life cycles. Common recreational practices, such as pottery, can still be completed, but the normal steps to get there are what must be changed. If an individual can slowly influence the world to implement sustainable changes into their daily lives, sustainable cultures can be built. Please

recall that instead of ultimatums, one can align on a spectrum of sustainability. Not all outcomes will be beneficial to the environment, but by consciously placing actions within the spectrum of sustainability, sustainable practices are gently put into play.

The History of Ceramics: Past and Present

Our world is incredibly dependent on our economic systems. A contributor to these economic systems is the lucrative and prominent ceramic industry. The practice of ceramics takes a superabundance of forms. Ceramic objects and vessels are utilized all around the globe, and their uses are extensive: jars, cups, plates, bricks, jewelry, and more. This is due to the materials excellent conducting and insulating capabilities as well as its pliability; Computer parts, automotive breaks, ballistic armor and electronic parts are just a few (Hein *et. al*, 2018; Pachaury, 2017). Today, ceramic objects and their uses have been fully integrated into our society. This material has been revolutionary to humanity and has been integral to its growth. but there are several drawbacks to the process of creating these objects. Specifically in the brick and tile industry, the practice of ceramics has created quite the scar on the Earth, and many ecologies suffer as a result of it. Ceramic industry pollutants have been destructive to multiple and various ecologies, and as a result a change is required in efforts to change the industry into one which operates within a sustainable framework. These changes are multifold; involving a change in energy sources, (in the case of this project, promoting the sustainable practice of alternative fuels) as well as changing the energy source which does not use the current supply chain.

The practice of creating ceramic objects has been conducted for tens of thousands of years. The very first ceramic objects can be dated relatively, the precise time of their origin is unknown. However, archaeologists have found fired ceramic objects which date back more than 24,000 years ago. These original objects did not serve a conventional function or utility, but were rather utilized for ritualistic purposes. Functional ceramic objects have been dated as far back as 6,400 B.C, roughly around the time where humans began to establish permanent civilizations near river beds. By 3,500 B.C. the ceramic process had been refined to the point where the controlling of fire within an incubated chamber was used to make objects structurally sound (Ganguly 2000). The revolutionary properties of ceramics slowly began to reveal themselves,

such as the collection and preservation of food was made possible. The knock on effect being the improvement of overall human health and well-being.

Ceramic objects truly changed the course of human history when the first bricks were created. Brick, arguably, is one of the most remarkable inventions of humanity. Bricks, with their excellent insulating capabilities and structurally sound nature, allowed for permanent structures, solid and strong structures, to be created. Bricks are noted as the first artificial building material to be created by humans (Cuce *et. al*., 2021). The utilization of bricks can be dated back to 10,000 B.C. where the ancient Egyptians hand shaped and sundried pieces of clay into shapes. These bricks however, were not permanent or weather resistant (Campbell, 2003). By 5,000 - 2,000 B.C. brick making had become a common practice in many parts of the world such as present day Iraq, Rome and parts of China and India. The world has already accepted bricks as its number-one building material (Zhang, 2018).

Fast forward a few thousand years to the present day, ceramics are still widely utilized in multiple cultures across the globe. Ceramic objects are resistant to erosion, and conduct heat and electricity incredibly well (Fang *et. al*. 1997). Their heat resistance and strength allow for ceramic objects to be used in automotive breaks as well as ballistic armor (Pachaury, 2017). Ceramic can also be used for water filtration which can be utilized for oil and wastewater separation (Chihi, 2019). Ceramics' multitude of uses makes the substance almost an absolute necessity across the globe. The economic sectors that various ceramic industries produce is extensive; In 2018, the global economic value was estimated at roughly $229.13 billion with a projected growth rate of 8.6% from 2019-2025 (Furszyfer Del Rio, *et. al*., 2022). Ceramics are not going anywhere soon.

Therefore, kudos and accolades to not just the history and importance of ceramics, but to the global ceramic industry as well. However, while the material may be inevitable, the problems associated with it are just as large. The ceramic industry and its issues run deep in society. The process leaves a scar on the Earth. Largely to blame for this are the brick and tile industries.

Annually, 180 billion metric tons of bricks are sold and an additional 340 billion tons of clay removed from the Earth yearly. When clay is removed (as a raw material) roughly 5,000 acres of topsoil are removed to harvest the clay. Where topsoil, and anchoring plants, are removed, erosion is not far behind (Pawar, 2014). The removal of the clay itself is extremely

land intensive and land damaging, unfortunately for this discussion the removal of dirt is not even the most intensive step of the process. The brick industry relies on fossil-fuels to physically fire the products, which requires a lot of energy to achieve the required temperatures. The two materials used the most in large industrial firings are coal and natural gas. In a Life Cycle Assessment (LCA) study of the industrial ceramic brick industry, S. Kumbhar, *et. al*. measured each individual release of emissions along the process of brick making from start to finish. The study found that the largest emitter by large in the brick sector was coal. The coal utilized in Asia was 32-71 Tons/100,000 bricks, and 16-19 Tons/100,000 bricks in India (Kumbhar, 2014). Additionally, the global brick industry is responsible for roughly 2.7% of global carbon emissions (Rauniyar, 2019). With the global appetite for bricks steadily on the rise, and the massive hit on carbon emissions associated, the brick industry has created a deadly positive feedback loop. With the codependent nature of humans and ceramic bricks, this paper argues that there must be a pursuit for more sustainable options when it comes to the industry.

Immediate action is required to rebalance the equation: too many people need bricks, however the total environmental damage due to brick creation is too great. As the leading pollutant that stems from this industry is the energy source (fossil fuels), a conversion to a new source of energy is required.

Finding the Best Alternative Fuel

The industrial brick industry, predominantly, is powered through the use of coal and natural gas (Kumbhar, 2014). The base material, clay, is abundant in the world, and has been the cornerstone for humanity for roughly 100 years; the material helps maintain our industrial production. However, the overconsumption and reliance on fossil-fuels like coal and natural gas have created a CO and CO_2 gas build up in the atmosphere; a replacement is an absolute necessity. Bricks require an immense amount of energy to be fired, and to maintain that level of energy, a material needs to be available that can meet these energy requirements for kilns. A session of industrially produced bricks have an average fuel consumption of 1.8 MJ/kg of bricks. The brick kiln itself can vary in fuel consumption, ranging roughly from 100 - 300 kg of coal per 1000 bricks (Nairobi, 1991). To find the material that best suits the large brick industry's energy requirements, this paper compares and contrasts a few materials which could best suit the

industry's needs. The alternative materials to fossil-fuels examined are electricity, wood and biofuels. The findings compare energy input, cost, availability and pollutants. These findings are compared through a holistic sustainable lens, while keeping in mind reusable materials and the extension of a material's life cycle.

As stated, powering a kiln requires a significant amount of energy (1.8MJ/kg of bricks) (Nairobi, 1991). The material that is best suited to complete the task of firing an entire session of industrial grade bricks must have an immense stored energy potential within it. Materials with "energy stored" within them have chemical energy. This means when burned, consumed or exhausted, a material releases a certain amount of energy which is displayed in joules (the unit for energy) (Energy, n.d.). Materials have a multitude of chemical energy potential. For example, coal has a chemical energy potential of 30 kJ/g compared to that of wood which is 10-14 kJ/g (Energy, n.d.). However, is wood still a viable option for industrial ceramic uses in the brick industry?

With a chemical energy potential of 10-14 kJ/gram of material, wood certainly has a non-insignificant share of energy stored inside (Energy, n.d.). Wood is also a natural resource, and has the ability to regrow after it has been consumed. Although wood has a reasonably high chemical energy potential, the problems associated with the harvesting of mass amounts of wood would lead to adverse problems for the environment. The sheer amount of wood that would be required to power the industrial sector of ceramic bricks would be colossal. Brick making already requires the use of wood in parts of the firing process, like processes currently used in Sudan. By using large amounts of wood, mass deforestation would quickly deforest parts of the world. Cutting out trees to aid our environment would have deadly consequences (Syed Asharaful Alam, 2009). The effects of deforestation are numerous. With the loss of organic root matter, soil would no longer have something to bind to, leading to problems with erosion. Water would no longer be able to be saturated if roots were removed, leading to lower water tables and freshwater supply. Also, trees' natural sequestration of carbon would be quickly cut off, therefore weakening available air quality in an area (Chakravarty, Sumit, *et. al*., 2012). Although wood is a renewable resource, the effects of using it for the industrial brick sector would be adverse and negative.

A second option for a fuel source is another cornerstone for industries historical exponential growth: electricity. A study conducted by C. Ronneau (2004) explored the energy

potentials of a variety of sources for fuel. Energy potential is defined as the amount of energy that can be released based on the mass of an object. Electricity contains a very low energy potential, so the amount of electricity needed to fire bricks on an industrial scale would be large (Ronneau, 2004). Comparatively, the price of electricity for commercially sold electricity in the state of Pennsylvania in 2023 is sold at 11.1 cents/kWh (EIA, 2023). Electricity however is a very sustainable option when it comes to development, and is still a popular and sustainable practice in small recreational ceramics. Electricity produces zero carbons when expensed, but has sustainable drawbacks in its industrial production and grid uses such as resource use and consumption (Jenkins *et. al*., 2018).

Looking for further sustainable alternative fuel sources outside of wood and electricity is the use of biofuels. Biofuels are a chemically produced fuel derived from feedstocks and animal fats. The process involves a rendering of either naturally harvested or used materials, commonly including soybean oil, corn oil and even waste vegetable oil (WVO). Biofuels are processed chemically through a process called transesterification. In this process, methyl esters are separated from the oil by combining both methanol and ethanol to any oil solution. Through this process, the methanol and ethanol remove the byproduct glycerin and leave behind a pure fuel ready to be used in any diesel engine (Knothe, 2015). The leftover material then goes through a series of washing processes as well as distillation (Tsai *et. al*, 2007).

Biodiesel's performance also outweighs its competitors. Realistically, any oil can be combusted within an engine to produce energy. Various oils such as peanut oil, biodiesel, standard diesel fuel and waste vegetable oil are a few (Knothe, 2015). Some energy sources such as straight diesel fuel or natural gas have an immense amount of energy potential stored inside of it, making it profusely efficient and a reliable source for the brick and tile industries source of energy. In terms of fuel consumption, diesel fuel ranks the highest. D'Alessandro *et. al*., displayed this in their study, where a multitude of oils was collected and utilized in a combustion engine. Each oil's energy capacity was measured, as well as their carbon oxide and nitrous oxide emissions. In the study, the standard diesel fuel was shown to have an incredibly similar energy output as a biodiesel mixture derived from feedstock, while using significantly less diesel fuel (D'Alessandro *et. al*. 2016). However, the emissions for biodiesel are significantly lower. In this same experiment, biodiesel was shown to emit significantly fewer carbons into the atmosphere compared to diesel fuel within the combustion engine. Biodiesel emits roughly 100 PPM, while

standard diesel fuel emits roughly 125-150 PPM; In this sense, standard diesel fuel could be compared to that of unrefined waste fry oil from restaurant fryers (D'Alessandro *et. al*. 2016).

As a large emitter of GHG's, the brick and tile industry should have to consider an alternative method of fuel. Natural gas and other petroleum based fuels may have a high energy capacity, but their associated pollutants are too great to ignore. Biodsiel however contains these sustainable attributes while having a larger energy potential than lets say a natural resource like wood. Hore-Lacy's (2011) study on energy density displayed differences in the material's energy potential. Biodiesel's energy density, or the amount of energy that is contained within the materials mass, is shown to be larger than coal and wood. Biodiesel's energy density simultaneously falls short of the petroleum based fuels: gasoline and diesel fuel (Pimentel, 1991) (Hore-Lacy, 2011). Biodiesel is also biodegradable, so the risk of contamination through spills or leaks can be lowered (D'Alessandro *et. al.* 2016). By switching to biodiesel instead of the current use of natural gas, the brick and tile industry would be able to significantly lower global GHG's, as well as a significant drop in particulate matter pollution. Biodiesel comes with disadvantages like its high chemical input and manufacturing process, but as it is derived from abundant natural resources as well as recycled materials, biodiesel would provide a great alternative to natural gas (Capuano, 2017).

Applying the Alternatives to Recreational Pottery

The practice of industrial brick making and large scale ceramic industry is detrimental to the global environment, but the global demand for bricks makes the practice a necessity. By switching to biodiesel for a source of energy, the brick making process would emit significantly less pollutants into the atmosphere (D'Alessandro *et. al*. 2016). However, the purpose of this project, this paper, is to demonstrate the utility of an alternative fuel and transition that practice to small-scale ceramics.

When choosing an alternative fuel for small-scale recreational pottery, biodiesel may have a few drawbacks. Biodiesel's negatives, when applied to small-scale pottery, are the energy and cost inputs. Other options can be used as a source of fuel, including non-chemically refined waste vegetable oil or waste fry oil. By comparing the pros and cons of biodiesel with unrefined waste oil, recreational potters would see that the unrefined material is advantageous for a source

of fuel due to energy and cost input of the biodiesel. Although when combusted waste oil has a higher amount of emissions, the sustainable practice of reusing materials, extending life-cycles and limiting chemical and cost input would benefit recreational potters.

As discussed above, biodiesel is advantageous when compared to its competition. Biodiesel produces significantly fewer emissions than fossil fuels when combusted, has biodegradable properties which limit ground contamination and can function well in almost any diesel engines (Bowman, *et. al.*, 2006; D'Alessandro *et. al*. 2016) . Although these properties are indeed productive and align with the nature of future sustainability, the use of biodiesel for small-scale pottery would have several negative drawbacks.

The first drawback of the use of biodiesel in small scale pottery is the steep energy input to produce this fuel. In a case study conducted by B. Esteban, *et al,* the researchers examined the entire life cycle of vegetable derived biodiesel that underwent the transesterification process. The biodiesel from vegetable oil was found to be less sustainably advantageous, as the energy and material input of the biodiesel process was high. This was completed by looking at the Energy Return On Investment (EROI), found by observing the ratio of energy obtained vs. energy consumed during production. The energy input of straight vegetable oil compared to processed biodiesel was obviously significantly lower, due to the sheer amount of energy and products used to produce the biofuel. The study concluded that the combustion of straight vegetable oil in a combustion engine (small scale) was advantageous because of vegetable oil's high energy capacity and low EROI. Although the emissions of burning straight vegetable oil was higher than the combustion biodiesel, the energy put into creating the biodiesel ends up being a greater investment for producers (B. Esteban, *et. al.,* 2011).

Applying this approach to small scale ceramics, using vegetable oil may be viable; vegetable oil is a clean material with low combustion emissions. However the use of straight vegetable oil in recreational pottery may have cost drawbacks, and its use in small-scale ceramics would not align with the goals of holistic sustainability. Another extremely advantageous oil that could be used in small-scale production of ceramics is the utilization of waste vegetable oil (WVO).

This is probably as good a place as any to restate the intent of this project as it's easy to lose sight of the goal(s). WVO is a front-runner in which one can maximize the objective of sustainability while staying within the parameters of a low cost, recyclable and energy efficient

material. WVO displays a similar energy potential biodiesel, even though it has not been chemically processed and treated (D'Alessandro *et. al.,* 2016). Additionally, The carbon emissions of WVO are displayed to be higher than both diesel fuel and biodiesel. Standard diesel fuel emits roughly 125-150 PPM of CO emissions, compared to WVO's roughly 150-160 PPM (D'Alessandro *et. al*., 2016). Although the emissions of the combustion of WVO is higher than petroleum based fuels, WVO is still a viable material for small-scale, experimental and recreational potters. Using WVO as a source of energy provides an extension of the materials life cycle. WVO is also abundantly available across the globe, as deep fat fryers are constantly filled and replaced with the material on a daily basis (Chhetri, 2008).

Now that we've focused on the goal it's time to transition from the theoretical to the practical. In that regard, the remainder of the paper will focus on how this was accomplished and whether stated goals were achieved. And then we can end up with a summary of outcomes and suggested future use.

Chapter 3: Process and Approach

The process and approach of this project will examine a few steps out of the industrial ceramic supply chain, and alter these traditional methods with more sustainable practices. The first aspect of this project will examine the natural harvesting and processing of local clay in order to create our ceramic products and vessels. The clay was locally sourced and carefully processed, leaving as little trace as possible to avoid large holes in the ground which can lead to erosion or still water.

The process involved the use of the alternative fuel waste vegetable oil (WVO), and harnessing its energy to power the kiln. The WVO had to be properly strained of all its contaminants before firing. To combust the material, a venturi burner was self-assembled using plumbing parts. The firing of the kiln was made possible by preheating the kiln with a propane burner, and switching on the WVO burner once the proper temperature was reached.

This project examined the utilization of an alternative fuel to execute the common practice of recreational pottery. This process uses alternative fuels to produce common ceramic products by employing methods of holistic sustainability. By employing these broader

sustainable practices to small-scale ceramics, the practice itself can be translated to the ceramic industries producing bricks and tiles at a large industrial scale. By implementing alternative fuels within a fossil-fuel dependent system like the brick and tile industry, sustainable practices can begin to assist in the deconstruction of hazardous supply chains. Additionally, by employing sustainable practices into recreational pottery, sustainable ideologies can be slowly implemented into society, thus creating a community of sustainably minded individuals.

Harvesting the clay

The first step in this entire process involved the harvesting of raw clay from a local clay vein located at Schreck Farms in Cochranton, PA. To harvest the clay, a small hole was dug near a shallow tributary stream of water leading into French Creek. Luckily, the clay that was found was abundant and pure, making the harvesting process both environmentally safe and time-effective. After around 70 lbs. of clay was removed, the shallow hole was refilled with the surrounding gravel and soil to limit an possible erosion.


Figure (1)

The next step involved was the drying of clay material. The large chunks of raw clay were broken up into smaller, more manageable bits and left out to dry (figure 1); the drying of the material took roughly over 1 week. After the material was completely dry, the processing could continue.


Figure (2)

To continue the processing of the raw clay, the material had to be properly filtered of all its contaminants. These contaminants include small pieces of sand, rocks and plant matter like roots. To filter out these contaminants, the dry clay chunks were placed into a bucket and filled with water. Over the next 3-5 days, the water slowly dissolved the muddy, sandy clay into a thick pasty material called a slurry. After a number of days, the slurry was blended into a watery paste (figure 2).

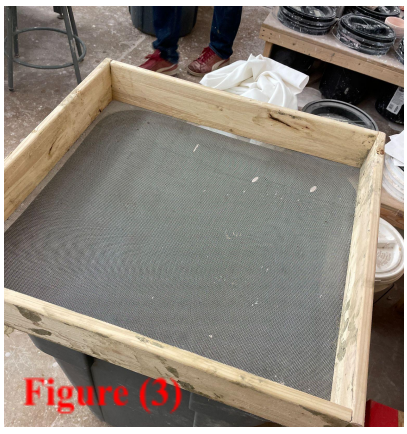
Figure (3)

Once the slurry was completely void of all chunks of clay, filtering could begin.

The slurry mixture was poured over a mesh screen, sieve, which was able to pull out the contaminants (figure 3) (small rocks, plant roots, etc…). Once the slurry was filtered of all its contaminants, the leftover slurry was almost pure clay. This was partially due to the quality of the clay vein which was used.

To further process the slurry into a usable clay body, the slurry had to be strained of its water. In the same mesh screen, a bed sheet was lined within it and the slurry poured over (figure 4); this would allow any excess water to be wicked off, leaving behind a large slab of extremely pure Pennsylvanian clay (figure 5). The excess water took about 2-3 days to be wicked off. When processing raw clay, it is important not to dry out the material too much in this step.


Figure (4)

After the clay had wicked away any excess water for these 2-3 days, the moist clay body was spread out on top of plaster in order to remove any remaining water, and make the clay body into a solid, malleable ball of clay (figure 6). From this step on, the balls of clay could be shaped into any form desired; For this experiment, a few vessels were thrown on the wheel.

The vessels consisted of a few vases, cups, bowls and test tiles (figure 7). These vessels were all bisque fired in an electric kiln, turning them into ceramic objects and preparing them for the next step of the experiment: The veggie oil kiln.

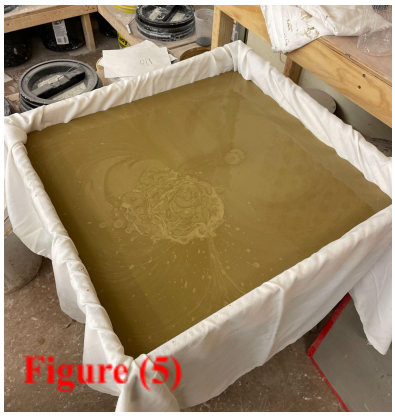
Figure (5)


Figure (6)


Figure (7)

Assembling the burner (Figure 8)

Assembling the burner took some time, as the burner had to be properly tested prior to the firing to ensure the procedure went as seamlessly as possible. The burner involved the use of a "venturi system." A venturi system involves the pressurization of a fuel source (WVO) via pressurized air. The pressurized air compresses the oil and atomizes it, allowing the oil to be sprayed and ignited; the burner was created by assembling brass plumbing parts (figure 8)

The first burner prototype ended up working well. The "tee" valve positioned towards the front of the burner regulated the oil coming into the burner, while the blue valve located to the rear turned the air injection on and off. To limit possible dripping- coming out of the front nozzle, an extension piece was added.

The plumbing pieces which were used included:

- 4" brass nipple extender
- 2x coupling and adapter (this attached the tee valve)
- ¼" tee valve
- 2" brass nipple extender
- ¼" blue copper valve

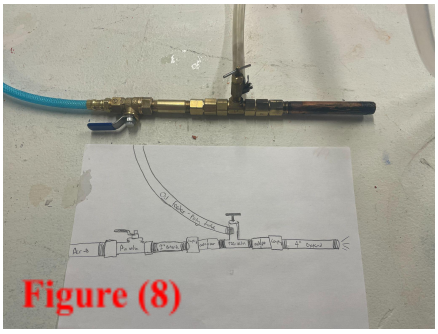
Figure (8)

The next step was to create the dispensary which would gravity feed the oil into the burner. The gravity fed system was simple. The bucket had to be elevated above the burner to ensure the oil would properly drip down and be pulled into the burner. To ensure there were zero leaks from the gravity fed bucket, a seal was created on the bucket with a few washers, rubber gaskets and a bolt to tighten the seal down; The copper "barb" protruding on the outside of the bucket was able to perfectly seal the hose which dispensed the oil into the

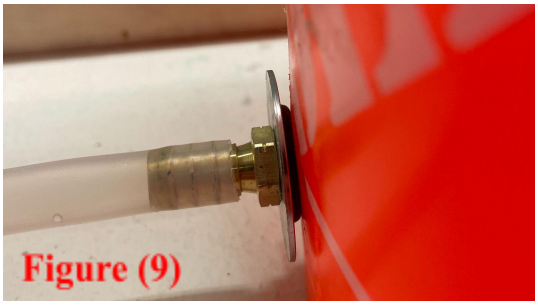
Figure (9)

burner (figure 9). The neon blue hose which is attached to the back of the burner supplied air from the air compressor, powering the burner itself.

Testing the Burner

Testing the burner involved the use of water to demonstrate atomization instead of using the oil. The gravity fed bucket was simply filled with water, and a ¼" poly hose was attached from the gravity bucket into the tee-valve on the burner (figure 10). The air compressor was then screwed into the back valve of the burner.

When testing the burner, some issues that arose was finding the correct pressure, and also limiting the amount of water which was not being atomized (figure 11) (water dripping from the end of the burner). The correct pressure which atomized waste the best was 40 PSI. This limited the amount of water actually being dropped out of the nozzle. Once the water tests were complete and the burner was properly atomizing the water, the experiment with firing the waste veggie oil (WVO) could begin.


Figure (10)

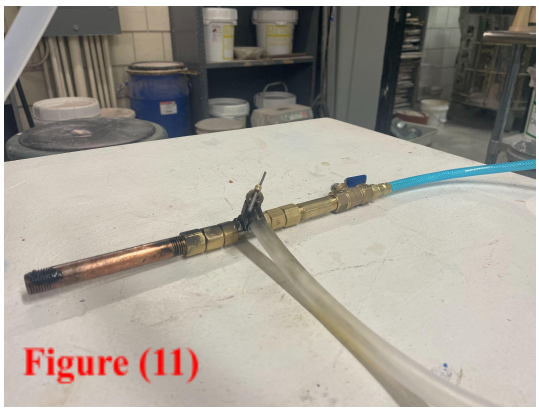
Figure (11)

Filtering the waste oil

The waste oil which was gathered was taken from the Allegheny Campus' dining halls. Almost every fast food restaurant utilizes deep fryers/fry oil, so the material was incredibly easy to come by. Once the fry oil was collected from the campus dining staff, the material had to be filtered to ensure a seamless firing procedure.

I gathered roughly 15 gallons of waste oil from the campus dining halls. Waste oil has to be replaced daily in restaurants, so the material itself contains barely any contaminants. Regardless, the material still had to be properly strained.

To strain the material, a metal mesh filter was used and the oil was strained into a 5-gallon bucket (figure 12). After the material was completely loaded into the bucket, the original containers were carefully washed and dried, and the oil poured directly back in (figure 13).

All 15 gallons of the waste oil were strained, which took about 30 minutes total to remove all the fry bits and contaminants from the oil itself; the oil was then ready to be used.





Setting up the kiln


Figure (14)

The kiln used was a tophat kiln. The kiln was able to be lowered up and down, so a base of bricks had to be created so the burner could have a place to rest. The base was created by using soft kiln bricks, with one hard kiln brick to support the burner (figure 14). The hard brick (protruding towards the center bottom hole) would allow for heat to be conducted, and would limit the potential for drips and spills within the kiln (figure 15). After the kiln was assembled, ceramic Kaowool was placed within the spaces between the bricks to ensure the chamber was properly sealed from the wind and snow. The kiln was then loaded up with all of the glazed ceramic vessels (figure 16).

Once the ceramic vessels were placed onto the kiln shelves, the kiln itself was lowered into position and prepared to be fired.

The burner was placed pointing directly into the base of the kiln, atop of the hard conducting brick protruding towards the center of the kiln. To ensure a tight seal as well as sturdy support, an additional soft kiln brick was laid into the final slot above the conducting brick. The hole was drilled and the burner was placed so the nozzle would be just above the conducting brick on the inside of the kiln (figure 17).


Figure (15)


Figure (16)


Figure (17)

Setting up the gravity feeder and the air compressor

The gravity fed bucket was placed on a table near the kiln, but around 2 feet above the burner itself. The temperature the day of firing was around 20°F, so the oil itself had to be preheated; this is due to the high viscosity of the WVO material. To ensure a steady flow of oil, a heating cable for thawing pipes was wrapped around the outside of the bucket (figure 18). This ensured that the oil would flow smoothly through the gravity-fed tubing (The oil itself was brought to around 70°F, but could have gone higher if the temperature was warmer). The air compressor was then set up a few feet away from the kiln and the bucket of oil.


Figure (18)

Placing the Pyrometer (Figure 19)

A pyrometer was inserted into the outside of the kiln to be able to accurately measure the internal temperature of the kiln. By using this device, we were able to gauge the exact temperatures within the kiln, and further examine how volatile the veggie oil was.


Figure (19)

Preheating the kiln

Vegetable oil has a flash point of roughly 600°F. This means the gravity fed burner would not simply be lit with just vegetable oil. Underneath the kiln at the hole in the center, an additional propane burner was placed to preheat the kiln. The propane burner was placed directly next to the hard conductor brick which the WVO sat atop of.

The propane torch preheated the kiln to roughly 700°F; this ensured that when the WVO burner was switched on, the WVO sprayed on the inside would instantly flash and catch fire. The kiln took 30 minutes to preheat and reach 700°F, which at that point the WVO burner could be turned on.

Turning on the WVO burner

To turn on the WVO burner, the air compressor was turned on at roughly 40 PSI. Then, the tee-valve on the burner was opened, allowing for the heated vegetable oil to be dispensed into the burner. Once the pressure had built up, the blue valve on the back of the burner was released, instantly atomizing the waste oil into the kiln.

Maintaining the temperature and switching off the propane burner (figure 20, 21 and 22)

Once the WVO burner had been switched on, the propane burner was then slowly turned down, allowing for the waste oil to do the remaining firing. The propane could not be completely shut off, so it had to be slowly limited until the proper temperature was created.

The propane was slowly limited for 30 minutes before finally being shut off. During this 30 minute interval of limited propane with full WVO injection, the temperature rose dramatically from 700°F to roughly 1700°F. Once at this temperature, the propane was completely shut off; The kiln reached a maximum temperature of 1976°F for the final leg of the firing on WVO alone.


Figure (20)


Figure (21)

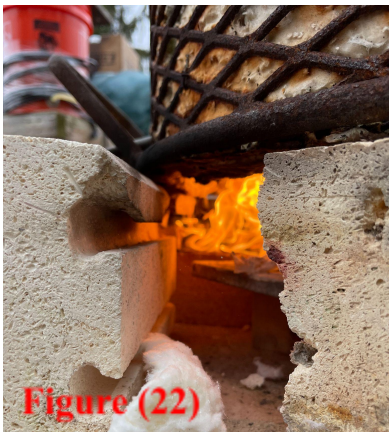
Figure (22)

Letting the kiln sit overnight.

The pots were visually inspected through the peephole once the kiln reached the target temperature (1945°F). The exteriors of the pots had a glossy finish, signifying that the proper temperature had been achieved. The pots were fired to Cone 04 (1945°F). The kiln was then shut off and the peep holes sealed, allowing the kiln to cool down slowly overnight.

Chapter 4: Results

Alternative practices and applying it to small scale ceramics for holistic sustainability

The final kiln results were 100% effective and achieved standard kiln firing results. The kiln was preheated to 700°F by using propane only. Once the kiln had reached 700°F, the WVO burner could be turned on, allowing the inside incubation to instantly ignite the WVO being injected into the kiln. The propane was then waned off for an additional 30 minutes; by waning off the propane, the WVO being injected into the kiln was ignited and further reinforced the propane in order to reach higher temperatures.

The air compressor that was used was an older unit, and due to the cold weather that day, it was not functioning to its full potential. If a newer air compressor was utilized on a warmer day, the amount of time used in the waning off process would have been less.

Once the propane injection had been completely shut off (roughly 1 hour into the firing) the oil alone was able to increase the internal kiln temperature from 1700°F to 1976°F. If a newer air compressor was utilized, the final number would have been much higher. Despite the drawback, it's very likely that the kiln was still 100% effective.

In total, only 2 gallons of WVO was used in the duration of the firing. The waste oil burner ran for roughly 1 hour, and in total the kiln took 1.5 hours to reach the final temperature of roughly 2000°F.

The finished pots fired to Cone 04 displayed fantastic results. The glazes which were used were standard clear glazes. The blue pots had a cobalt tint applied to the clear glaze. The WVO charred up some of the pots quite well (a positive thing in small scale ceramics), and overall the waste vegetable oil atmosphere created results which would be difficult to mimic in a standard electric or gas kiln.

This demonstration proves that alternative methods can be successfully used in order to achieve a product which is comparable to the standard methods of firing. While the natural gas product, propane, was used, it is important to note that the use of WVO reduced the amount of propane that was required to achieve the desired temperature. Additionally, the practice only utilized 2 gallons of WVO, which is significantly lower than initially expected.

The propane fuel source was only utilized for about 1 hour, with a steady decrease in use for the last 30 minutes of that duration; this could be comparable to a grill session on a common propane grill. In combination with the WVO burner, this not only worked, but reduced quantities of both fuel sources. In both industrial and recreational ceramics, this project would not only be environmentally viable but economically more cost effective .

If a newer and larger air compressor was supplemented, and the firing occurred on a warmer day, significantly less amount of propane would be used. This would also allow for a greater amount of WVO to be burned; Results also suggest that the quantity of WVO used would be less; again suggesting a cost savings.

Regardless of the air compressor and the weather, the kiln's success indicates it would be a viable option for a much larger range of temperatures, not just Cone 04 at 1945°F. This methodology could be applied to a range of temperatures, as the WVO was a viable option for an alternative fuel.

The vegetable oil's burner's design and placement could have been improved as well. For this experiment, only 1 conduction brick was utilized near the front of the burner. If 2-3 more bricks were placed along the bottom of the kiln, the chamber would have been incubated more evenly. However, changing this may yield different results in the glaze patterns, as some of the marks and blemishes on the vessels are a direct result of being next to the burner's atomization range.

In total, the WVO burner can be seen as a success test proving our initial theory. While the pre-heating with propane did utilize natural gas, the result used a paltry 2 gallons of WVO. This experiment is both economically and environmentally viable; both positive outcomes. Further supplementations by newer equipment would have made the experiment more efficient, but despite this the burner still obtained an accurate and suitable temperature in which to glaze the vessels.



















Chapter 5: Conclusion - Inspiring a Community with Sustainable Practices

Alternative methods are important for separation from the standard supply chain. This project involves an integration of stability into a larger community by introducing alternative practices which defer from the common and unhealthy and currently used supply chains.

This project *will* emit GHG carbons. The practice of ceramics itself creates waste in many of its steps, especially at the large industrial scale. Every step must be critiqued, from harvesting clay and the energy used to fire the finished objects requires some derivative from where it can be produced. But focusing on large scale ceramic industries like the brick and tile industry, a definite change is required. The purpose of this demonstration is to be an analog for the larger ceramic industry and outline the problems that are associated with larger industries whose focus will be applied to a smaller scale representation of the issue. The demonstration at hand examines the idea of holistic sustainability and explores the options and conclusions that can be drawn from it. *Sustainability does not mean ceasing production. Instead, it means questioning current methodologies and operational procedure.* These current methodologies include our carbon dependent systems which drive our economies. However, sustainability, in this sense, offers new options that can be utilized to achieve common goals. By examining sustainability with a holistic spectrum, our everyday recreational activities can still be carried out. This is done by switching away from overly carbon dependent systems, breaking supply chains and extending recyclable materials life cycles.

The switch from carbon-producing fossil fuels is vital to our sustainability goals. Global carbon amounts are increasing by the minute, to limit this accumulation of carbon based fossil fuels need to be slowly phased out of our daily lives. According to Chen *et. al.*, (2022), the global carbon average of atmospheric carbon dioxide has risen from 285 ppm to 419 ppm from pre industrialization until now (1850-2022). This is shown to have increased global temperatures significantly, raising ocean temperatures and churning out natural disasters on a continuous basis (Chen, *et. al.*, 2022). The accumulated effects of the industrial revolution until now have stemmed from fossil-fuels. By engaging with this project, the practice of using alternative fuel

sources can be brought to attention, further inspiring others to take up the practice of abandoning fossil fuels as a necessity.

Along with ceasing fossil fuel use as a personal goal, the practice of reusing or repurposing materials can also help reduce the amount of waste we produce…. Materials have a life cycle; many products are single use, as in, they are used one time and their potential is spent – fossil fuels are just one of many single-use commodities humans use on a daily basis. This project's demonstration displays the use of a fuel source which is commonly used on a daily basis (various cooking oils, etc.). By using this otherwise used or spent material, waste fry oil can be repurposed and extended, employing sustainable practices. C. Lund *et. al*. (2008), describes this approach as thinking of a material from 'cradle to grave.' By employing this sustainable tactic, the lifespan of a material can be lengthened by utilizing it for a new or different purpose (Lund *et. al*., 2008); in this case, a fuel source for firing a kiln. By extending life cycles of products, sustainable utilization of materials ensures that new products won't be used until another is fully worn down. Generally speaking, the fewer products being used in our society, the less likely it will be for pollutants to be expelled, thereby employing sustainable practices. By limiting the use of certain products and using alternative methods of production to achieve goals, common and destructive supply chains could be broken.

The problems that we associate with our changing climate and ecological issues can be attributed to production via the supply chain. Supply chains are everywhere, many times invisibly so, and our commodified society relies on them. However, employing practices to remove yourself from the chain, even if it is just a few steps from the process, is important to sustainability. This project for example examines the ceramic supply chain, and addresses issues partly with the extraction of materials, but predominantly the source of fuel being utilized. All of these sustainable practices intertwine with the ideas of holistic sustainability, layers can be addressed at once. By employing these sustainable practices to a communal and recreational activity like pottery, sustainable change can be implemented through the spread of ideas. To restate: although this the ceramics industry is a small part of the overall economic engine, it too has an environmental cost. Highlighting the ceramic practice suggests that ceramic industries are not the only industry which can benefit from reviewing all ecological inputs and reconstructing them in a sustainable matrix. Numerous supply chains around the world have been locked into carbon dependency; breaking out of this typical mold of fossil-fuel reliance within corporate

industries would be positive for ecologies around the globe. In short, the less fossil-fuels being combusted, the better.

An unspoken but central tenant to this project is its possibility to be integrated into social systems. The purpose of exploring holistic sustainability is the action of integrating its methods into these systems, to further grow a community of "sustainable actors." These alternative routes to completing an enjoyable recreational activity like ceramics not only exposes the issues with ceramics, but presents sustainable ideas and practices for people to utilize. The ceramic community as a whole relies on other voices to carry out its methods, teach skills and much more; this project does the same by involving groups of people and planting ideas of sustainable practices within a community. Simply put, this project is an exploration of small scale change for the ceramics community. This project not only poses the ideas of sustainable alternatives, but that these sustainable practices are efficient and environmentally beneficial.

The success of this project was important for a few reasons. While the experiment utilized propane (a natural gas), its mixture and incorporation with WVO limited both fuel sources. If this methodology was applied to the larger scale brick industry, it would see major cutbacks on the utilization of carbon-dependent fossil-fuels; this would be a huge step towards our sustainable goals of freeing ourselves from fossil-fuel dependent systems. Another beneficiary to this success of this project was its practicality, proving that its use not only worked, but worked quite well. The firing not only reached the correct temperature, but it did so in a short and efficient time frame. Again, if applied to the larger industry, the time-based economic demand would not be affected at all. Finally, shrinking down these large scale implications, the projects demonstrated communal interaction in the realm of sustainability. Two potters (myself and Professor Thomas) utilized an alternative fuel to complete an enjoyable recreational practice. The success of this project further allows the spread of sustainable knowledge to not only ourselves, but the broader ceramic community. For this project, the spread of sustainable ideas was passed along both from student to educator, as well as potter to potter. The distribution of ideas can help integrate sustainable practices into our daily lives.

Sustainability should be utilized as a tool (a process, a methodology, and a measure), rather than a limiting agent. By eliminating a practice and suggesting that it ceases to exist, you have done nothing to grow but rather have only destroyed. The central purpose of this paper was exploring how sustainability and growth could grow in parallel. This project provides an

alternative vision of the future for the current ceramic industry (and industry practices). The practice, the art, of ceramics and brick making does not need to be eliminated, but the way ceramics are generally produced does require reconsideration. By replacing one or two important steps within the process, the practice of pottery (ceramic/brick making) can continue into the future. This is made possible by the extension of life-cycles, using recycled materials and artists and industrial workers alike more consciously aligning themselves along the spectrum of sustainability.

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