Rosebud Continuum Team Project Final

Concepts of Sustainability

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Executive Summary

A linear economy, like our current one, promotes a take, make, waste system but this is not suitable or sustainable long term. At Rosebud, nothing goes to waste, everything serves a purpose that supports symbiotic relationships. Everything from the decaying trees, small branches that act as a landing strip for birds in the pond, leftover food scraps, even animal and human waste gets utilized as a resource. This concept of sustainability extends through efforts on and off Rosebud, this sustainability center is a sanctuary that serves as an example of what is possible when we think critically, redesign, and reshape our relationship with finite resources and the ecosystem. Biodigestion serves as a sufficient way to solve a variety of real-world problems such as food waste and utilizing renewable energy sources by creating a closed system. This approach to using waste as a resource has been a sustainable practice in action at Rosebud, but we suggest revitalizing the

Food waste, soil degradation, and invasive species are proven to be problematic, but biodigesters, like the ones seen at Rosebud, can be utilized as a widespread solution. The Bishops' had an ecological assessment that canvassed and catalogued the plants on the property which revealed that a variety of invasive species were competing with native plants. As a form of maintenance, the Native Plant Society and others are welcome to volunteer in the monthly invasive plant removal. The biomass accumulated from the invasives are usually left in a pile to be burned or composted, but seeds can disperse and spread with these methods. We suggest treating biomass with an enzymatic hydrolysis pretreatment that makes the fibrous plant matter easier to digest. These enzymes are mostly composed of fungi that breakdown complex cellulose chains and make it into a usable form of carbon accessible in the biodigester (Amapex Admin, 2021). Some of the most prevalent invasives identified include wedelia, cogongrass, skunkvine, ceasarweed, and more. Managing these invasives, pretreating and biodigesting invasives properly disposes of them and simultaneously generates energy and effluent that can be used as a fertilizer or potential bedding for the goats. All throughout, we consider the various components of biodigesters and challenges of digesting lignocellulosic biomass

Biodigestion occurs in four stages, pre-treatment, digestion, processing biogas, and reusing digestate. Altering treatment in any stage has implications that affect biodigestion and biogas generation. Taking that systematic approach into consideration, we suggest pre-treating fibrous green biomass, like invasives species, via enzymatic hydrolysis, or exploring medicinal and edible options. We aim to expand on Rosebud's already successful projects and educate others about how to take sustainable action in their own hands, whether it is directly feeding food scraps to the biodigesting dragon or getting involved in the invasive plant removal, there are a multitude of educational and sustainable outreach opportunities at Rosebud.

Introduction

Biogas has been around for centuries, legend has it that biogas was first used in Assyria in the tenth century BC to heat bath water. But more recently, in the seventieth century Jan Baptista Van Helmont discovered that decaying organic matter creates a flammable gas. In 1776, Count Alessandro Volta determined a correlation between the amount of decaying matter and the volume of gas produced, 32 years later Sir Humphry Davy distinguished methane as a present gas in anaerobic digestion of animal manure (Extention, 2012). It was not until 1859 until India built the first operational biodigestion plant. Later when anaerobic digestion reached England, biogas became acquirable through solid waste, and it was later used to power streetlamps in the city. By the 1930s, the studies of microbiology evolved and led to the discovery of the role anaerobic bacteria plays in the digestion and decomposition process which reveals how methane is produced (Extension, 2012). This finding explained the scientific process of anerobic microbial digestion facilitates decomposition and the creation of a renewable biogas. In 1979, Mason-Dixon Farms created the first plug flow digester that made the manure of 1,700 dairy cows' manure into energy to use on the farm (Goldstein, 2009). It has since been used to help farmers safely dispose of animal manure, prevent agricultural runoff, and instead turns waste into a resource. Biodigestion is even beneficial for the municipal waste sector as it reduces waste through source reduction which then reduces the cost of waste disposal.

Turning biomass into a biogas is a simple, straightforward process that can be replicated anywhere with biodigesters. This efficient system has proved to be a sufficient means of preventing methane emissions by turning the plant and organic material to fuel that serves as a renewable energy source. Traditional sitting methane is a high-impact greenhouse gas but transforming it into a biogas turns waste into a resource. The Environmental Protection Agency recognizes biodigesters as a way forward with waste, but all anaerobic digesters must comply with local, state and federal regulations and attain proper permits to ensure air, solid waste and water quality standards are met. The essential parameters used to maintain efficient biogas production include many physically and chemically specific components. For instance, the content of organic materials and effluent which act as a digestate is crucial for the maintenance of these biogas systems. As per the EPA guidelines, these systems must be contained aboveground on an in-ground tank and must include a pump to transfer the waste into the digester (EPA, 2012). As seen at Rosebud, the Dragon, the Wishing Well and the covered mound biodigester are composed of the same model just on different scales. The Dragon at Rosebud has the capacity to supply up to one-hundred people with biogas, on the property there are three main digesters and seven ancillary digesters. Biogas can be utilized as onsite fuel with little processing and the reduction of hydrogen sulfide, but when it is to be sold as a renewable natural gas it must be thoroughly refined by processing carbon dioxide, hydrogen sulfide, ammonia, and other impurities out of the biogas.

Rosebud is a sustainability sanctuary that is home base for many environmental experiments; between the native trail, the food forest, solar panels, the beehouse, the compostable toilet, and mostly interestingly the biodigesters and invasive species. The central focus of our studies at Rosebud is centered around removing invasive species, pretreating it, and feeding it to the biodigester to create energy and fertilizer. Figure one is a photograph of one of the biodigesters present on the Rosebud property, it is referred to as the dragon digester. In other instances, to promote food sustainability by preventing food waste, with the help of aerobic digesters waste gets put to work. The generation of biogas reduces greenhouse gas emissions by harnessing methane and using it as a fuel, the rich effluent remaining from digestion can also be utilized as a fertilizer as an alternative to synthetic, in-organic fertilizers. Biodigestion applies many concepts of sustainability and creates a circular system that is inclusive of waste and revitalizes it as a resource.

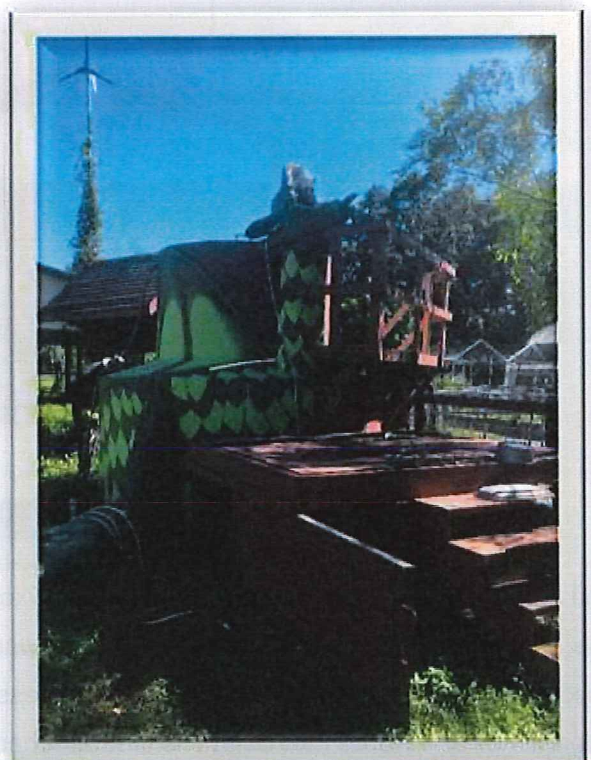


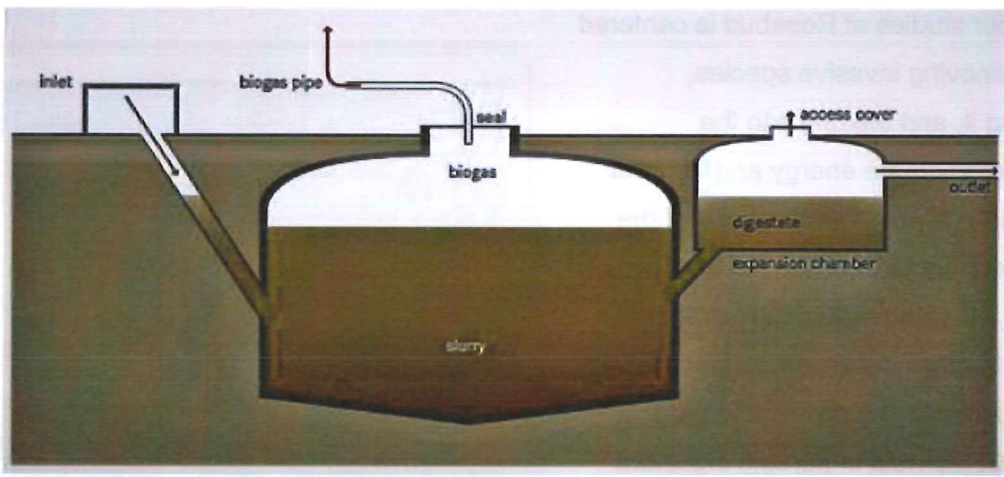
Figure 1

DRAGON DIGESTER AT ROSEBUD CONTINUUM, TAKE BY ANDRES CABRERA

Sustainability Project – Literature Review

The idea of sustainability or sustainable practices is to meet our own needs without compromising the ability of future generations to meet their own needs. While many think that this definition relates to just the environmental impacts one needs to look at the social and economic impacts as well. The use of biodigesters to convert food and plant waste, specifically plant waste from invasive species, into fuel and fertilizer can help limit our reliance on fossil fuels and help fight the effects of climate change.

Anerobic biodigesters, like the one shown in figure 2, work through a process that utilizes bacteria to break down organic waste, organic waste can include animal manure, food waste,



Schematic of a biogas reactor. Source: TILLEY et al. (2014)

Figure 2

ANEROBIC BIODIGESTION SCHEMATIC, SOURCE SSWM

and plant material (EPA, 2021). Biodigesters, like the three that can be found on the Rosebud site, use anerobic digestion to break down the waste into biogas and digestate, digestate is the solid and liquid biproducts of the anerobic process. Biogas is a biofuel that contains approximately 40-60% methane, this methane can be burned as fuel for electricity and even processed further to be used as fuel for cars (Advantages and Disadvantages of Biogas, 2021). Digestate, on the other hand, can be used as animal bedding, fertilizer, compost, and soil. This process helps create a circular economy, though as with all technology there are benefits and disadvantages. The benefits to bio-digestion are that it is eco-friendly, reduces soil and water pollution by reducing the amount of material that goes to a landfill, and produces an organic fertilizer that can be used thus reducing the need for chemical fertilizers. The disadvantages include a limit in technological advancements for large scale production that make biodigesters an inefficient technology, impurities in the bioproducts that can limit the market for use, and logistically this technology would be incompatible in a city environment (Costa, 2015). Another disadvantage is lack of government initiatives to implement biodigesters at a large scale. Particularly in rural regions and developing countries, this has limited their use and expansion. For this reason, some regions still heavily rely on fossil fuels for energy production (Angula-Mosquera, et al., 2021). It will be difficult to implement biodigesters in a sustainable economy without the support of government and elected officials.

Approximately 1.7 million acres of Florida's open spaces have been invaded by exotic and invasive species, these invasive plants destroy more natural habitat every day than development (UF Florida Wildlife Extension, 2021). The secondary focus of this project is to educate and reduce the impact of invasive species firstly in Hillsboro County and then throughout the State of Florida. Approximately 1,400 exotic plants have be introduced to Florida's environment and of those 6% are considered to be invasive (Why Manage Plants, 2021). While this may not seem like a detrimental amount invasive plants usually grow aggressively, have a high reproductive rate, and are poisonous to the animals in the area. Invasive plants can bring invasive insects to the area and can have a detrimental effect on native plants and the soil. The ability to rid the area of these invasive species will not only improve the ecosystem of the area but also reduce the amount of water and pesticides that are needed to control the population. Secondarily, using the biodigestion process we will be able to eliminate the invasive species while producing clean energy and byproducts. In order to use invasive species in the production of biogas a large problem will need to be overcome, the biodigesters at Rosebud cannot currently use fibrous or cellulous materials as they do not breakdown.

Biogas that is generated from methanogenesis can be used as a renewable resource; it is a clean non-polluting energy source that utilizes methane as a fuel instead of a source of pollution. When measuring outputs like biogas and digestate, total plant volume can determine plant capacity. The digester volume is the maximum amount of biosolid slurry the tank can hold and the gas storage volume that measures the amount of gas held within the tank; to find the total plant capacity, the digester volume and the gas storage volume and be combined (IRENA, 2016). It is important to add the right amount of feedstock and water volume to properly maintain the tank. Digestion time is dependent on the total solid content and the volatile solid content and temperature can impact the speed of biogas production (IRENA, 2016). After considering these variables, the feedstock retention rate is used to determine the amount of time it takes for feedstocks to circulate through the digester, it can be calculated by dividing the digester volume by the total feedstock volume (IRENA, 2016). When the basics like plant capacity, feedstock retention rates and biomass weight are accounted for, then biogas can be measured. There are various methods to measure biogas production including appliance use, feedstock use, fuel substitution and direct measurements. The most effective way to estimate biogas production is through the direct measurement technique that monitors and records biogas production with the use of mechanical devices. This may not be financially feasible in all operations, opting for appliance or feedstock use methods may be easier to facilitate. Appliance use measures energy output by the hours of energy per day provided, and feedstock use calculates biodigester size and feedstock use to determine the anticipated biogas produced (IRENA, 2016). We intend to read more and work on the biodigesters at Rosebud to determine what the best method of measurement is.

Project Overview

Background Information of the Project

Rosebud Continuum is an educational and research area located in Land O Lakes in Pasco County, Florida. Rosebud includes many structures related to sustainability such as greenhouses, solar panels, community gardens, bird houses, bat houses, and biodigesters. Biodigesters will be the central focus of our research because waste and sustainable material management are integral in every project at Rosebud. There are many biodigesters on the property, but the main three of varied sizes are located within the facility and have been used for educational purposes and for on-site energy production. We will focus on how the anaerobic digestors work, analyze their benefits, and how they contribute to concepts of sustainability. Such concepts examined in our research include water, energy, food, entrepreneurship, business, and climate change adaptation and mitigation. Our research will focus on their impact of waste management, land management, economic benefits, and community engagement on the site.

Sustainability Efforts Already Included in the Project

Once you step foot at the Rosebud Continuum it is easy to see the efforts already underway to promote and advance our understanding of sustainability and the impact it can have on our environment. Rosebud is, first and foremost, a center for sustainable education and research that utilizes community focused environmental initiatives to help promote ecological stewardship (Mission Statement, 2021). This commitment to sustainability is the backbone of the center, which is evident in their mission statement, it is to preserve culture and engage the community through sustainability education and development (Mission Statement, 2021). There are a multitude of projects and developments that are currently underway on the site such as: a bee colony, bat and bird houses, utilization of alternative energy sources such as solar panels, hydroponic and aquaponic agriculture, and waterless toilet facilities. The team at Rosebud utilizes these projects to further our understanding and ability to reduce our impact on the planet.

The bee colony, bat and birdhouses serve as an ecological aid as these additions of houses and hives provide shelter for a multitude of bats, birds, and bees. The bee colony is housed in a wooden building with wooden honeycomb cutouts, inside an infrared light luminates the room but does not disturb the bees. The hive can be seen in a clear-glass structure, this addition allows people to see the mechanics of hive-building and get a deeper understanding of the ecological benefits of bees from pollination to honey creation. The birdhouses are made from hollowed out gourds and can be found along the native plant pathway near the pond, it provides a safe space and shelter for the birds near a source of water. The bat houses stand tall and are home to over a thousand bats, their home base is also near the water as bats usually drink before forging for food at night. Rosebud is an ecological niche fit to serve an array of flora and fauna, the minimalistic approach mimics the natural environment and encourages people to appreciate native beauty, rather than artificially landscaped environments. The ecology at Rosebud has remained resilient and the Bishop's are resistant to the development of the surrounding area. They have been in a constant battle trying to buy more land to protect it, but private entities with their own interests try to stifle their sustainability efforts.

Some of the other elemental projects at Rosebud include the solar panels, the compostable toilet and both the aquaponics and the hydroponic towers. The solar panels are one of the essential on-site renewable energy sources. There are solar panels scattered around the property and they provide energy for the homes and RVs on-site. Recently, the golf carts got solar batteries and now charge under a pavilion with an opening that allows the panels to charge. Rosebud symbolizes that there are many ways to do things, but it is important that we do things mindfully and our practices are considerate of the ecosystem around us. This closed system thinking can also be seen with the hydroponics and aquaponics; overall, both systems require less water, accelerate plant growth, and minimize weeds. With aquaponics both the fish and the plants contribute to the system, the plants filter the water for the fish and the fish excrement acts as a fertilizer for the plants. Both are simple, self-sustaining systems that are low maintenance and seeing this project in action at Rosebud goes to show that this shift in agricultural practices and energy acquisition are feasible, it proves that there is a better, more sustainable way to live in tandem with the planet, if it can be done locally, it can be done globally.

One of the key sustainability projects currently in place at Rosebud is the identification, removal, and disposal of invasive species on the grounds. When Rosebud was first started the grounds were overrun with Brazilian Pepper (Schinus terebinthifolius) and Camphor (Cinnamomum camphora) (Kuras, 2021). The team worked onsite to contain, remove, and prevent the further spread of the species. The images below illustrate how overrun the area was prior to the invasive removal. In the top right image, the pond is barely visible behind the trees and overgrowth. In the middle right image, the Brazilian Pepper roots and impaired the visibility of the pond. The last image reveals the piles of roots and branches waiting to be burned and it also depicts how much area and land was cleared up for natural species after the invasive removal. Rosebud continues to educate the community and ensure that any species found on site are identified and carefully removed, they also have an invasive species plant removal event once a month where volunteers can visit the site and help remove the identified invasive plants.

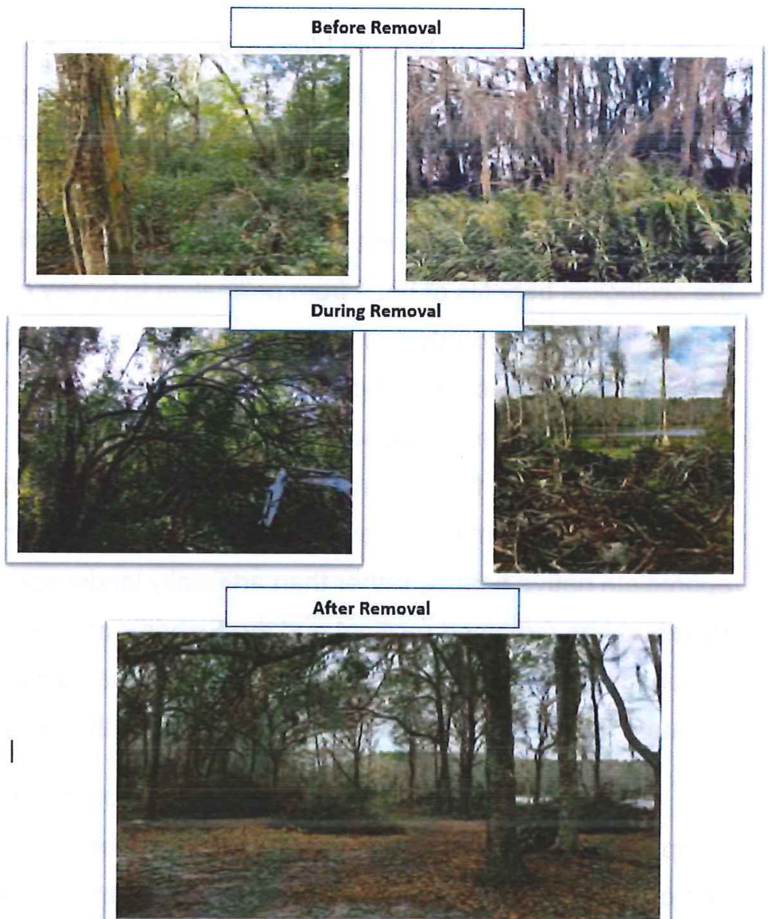


Figure 3

INVASIVE SPECIE REMOVAL, ROSEBUD CONTINUUM

IMAGES PROVIDED BY MICHAEL KURAS (KURAS, 2021)

Applied Sustainability Strategies

The main benefits of utilizing a biodigester for fuel and its biproducts is that biodigesters are a renewable energy source, they utilize waste in the production process, and they create a circular system that helps facilitate a circular economy. Utilizing waste as a fuel for the biodigester means less material gets sent to a landfill to decompose which in turn reduces the amount of land that we need to clear for waste and a reduction in the amount of greenhouse gases produced by decomposition. What if one could kill two birds with one stone? By utilizing invasive plant species for fuel in the biodigester process it can eliminate the negative impact invasive plant species take on the Florida ecosystem while simultaneously creating a demand for organic fertilizer thus generating a profit bearing business. The top five invasive species in Florida are Skunkvine, Brazilian pepper, Australian Pine, Melaleuca tree, and Old-World Climbing Fern (Thomas, 2019) and at Rosebud Continuum the main invasive species are cogongrass and wedelia. Cogongrass was first introduced into Alabama in 1911 from Japan via packaging material and wedelia was introduced in 1933. Invasive species are characterized by their fast growth rate, rapid reproduction, and high dispersal ability which means that they can spread their seed easily and in a great area. What if instead of using herbicides and weedkillers, which are a nightmare for the environment, a person could collect all their invasive species and donate them to a site to be used in the bio digestion process? By using these plants in the biodigester process not only will this work to eliminate the impact of invasive species on the ecosystem, but it also creates a stream of revenue and raw material for the bio-digesters. The one roadblock to using invasive species in the process is that lignocellulosic biomass and fibrous material can be more difficult for the biodigester to breakdown without the physical and mechanical pretreatment process that helps improve particle densification and enzymatic accessibility (Amin et al., 2017).

The use of biodigesters offers communities benefits as an alternative to properly dispose of organic waste, rather than landfills. This can open an opportunity for the disposal of food waste. According to the FAO, about 1.3 billion tons of food waste are generated each year with. Developed nations account to 670 million tons while developing nations produce an estimate of 630 million tons of food waste. This amount of waste poses environmental repercussions as well as sanitation issues for communities (Granzotto, et al., 2021). Food waste can occur at any point from initial production, transportation, preparation, and consumption. For example, in the hospitality business about 33% food served ends up being becoming waste with an estimate of 1 kg produced by guest (Paras, et al., 2020). Globally, this has huge implications. Currently the world produces enough food for everyone to be fed and have food security, however, 690 million people worldwide go hungry with about 3 billion cannot afford a healthy diet (International Day of Awareness on Food Loss and Waste Reduction, 2021). So much food that can feed populations end up occupying landfills. In addition, all the resources lost to food waste would be given another purpose as this source will be then converted into bioresources. It is estimated that 24 percent of freshwater, 23 percent of cropland, and 23 percent of fertilizers used for food production are lost when food becomes waste (Thyberg, 2016). The loss of resources needed to produce food also cause negative environmental effects such as deforestation, loss of biodiversity, pollution of water ways, aridification, and loss of soil fertility. Food waste also adds greenhouse gases into the atmosphere from its breakdown in landfills and from the extraction of resources needed to produce food. Globally, food waste generates about 4.4 GtCO2 eq, which accounts for 8 percent of greenhouse gases emitted. To put this into perspective, if food waste was a country it would be the third largest emitter of greenhouse gasses (FAO, 2021).

Figure 4

SOURCE: (FAO, 2021)

Biodigesters can alleviate the amount of waste that ends up in landfills and turn them into a variety of bio products. Food waste can be converted into a versatile number of resources such as fertilizers, biogas, and biofuels. Food waste biproducts can help with climate change mitigation since they can replace fossil fuel resources. Biodigesters will also help reduce deforestation rates in communities that still heavily rely on the use of wood fuels as a main source of energy. According to the UN, about 3 billion people worldwide still rely on wood, coal, and charcoal for heating and cooking purposes (Nations, 2021). This allows the use of food waste to become sustainable since it can minimize a community's carbon footprint, allow them to use a local resource, and enjoy economic benefits since they can sell products from the biodigester. Using biodigesters will also allow populations to implement goal 7 and 13 of the

United Nations Sustainable Development Goals of clean and affordable energy as well as climate change action (Nations, 2021). By producing clean energy communities will be reducing their greenhouse gasses emissions thus mitigating their impacts. In addition, the use of food waste can alleviate the debate of food versus energy for communities (Eriksson, Bisaillon, Haraldsson, Marteen, & Sundberg, 2016). There is concern that large quantities of food produced will be allocated for the energy sector, further putting a strain on food security and present challenges to malnourished communities. Implementing food waste will help solve this dilemma since the biodigester will be using food that is going to be discarded rather than that intended for consumption.

Biodigesters are beneficial at facilitating a circular waste to energy system as they utilize food waste and animal byproducts to create clean energy and enriching fertilizer. Biodigesters are particularly helpful at reducing point source pollution by managing manure at the source, collecting it to break down and co-digest prevents it from becoming runoff to fuel the next algal bloom. Containing this animal byproduct and putting it to use generates biogas, or biomethane to be used as fuel, it also creates digestate, or biosolids that can be used to add nutrients to the soil, it can be used as a fertilizer or added to bedding for livestock (ESSI, 2017). Biogas yields a high volume of valuable solids, liquids, and gases that have a multitude of uses that range from energy creation to soil amendments; mixing food waste and livestock waste in the same biodigester encourages co-digestion which improves biogas yields. Similarly, keeping a warmer temperature in the biodigester, between 86-100 degrees Fahrenheit increases efficiency and reduces the time it takes to break down waste. This process is called mesophilic anaerobic digestion Either way, raw biogas, digestate, or refined biomethane, they provide endless renewable energy opportunities. Biogas and biomethane are renewable energy sources that contain about 50-70 percent methane, 30-40 percent carbon dioxide and a remainder of other scant gases. Biogas produces heat and electricity to turn microturbines, engines, and fuel cells, the biogas can be refined and processed into biomethane that is a renewable natural gas that can be utilized as fuel for cars or injected into natural gas pipelines (ESSI, 2017). This works as an intricate system that innovates waste and creates a renewable resource and revenue opportunity, this can revolutionize the way we work with waste, reduce greenhouse emissions, and lessen our dependence on fossil fuels by filling that demand with a renewable energy resource.

Proposed Recommendations

One recommendation is to use invasive species as biomass for the bio-digestion process. This process will provide the biodigester fuel and allow Rosebud a source of revenue. They could allow the community to donate its flora waste for a discount on fertilizer, which is a bioproduct of the biodigester. This program will not only inform people about the invasive plant species of Florida but also provide a revenue stream for Rosebud in terms of fertilizer. As of today, there are an unlimited amount of invasive plant materials that can be utilized as fuel for the biodigester. This proposal will educate Florida visitors and residents, which is difficult as the majority of people in Florida are from out of state. From April 1st, 2019, to April 1st, 2020, 387,479 people moved to Florida, this means that the number of people who cannot identify invasive species dwindles (Tampa Bay 10, 2020). Our recommendation is to create a class at Rosebud that would help teach the residents of Hillsborough, Pasco, Pinellas, Manatee, and Sarasota counties the difference between native and invasive species. This will allow Rosebud to educate the native and incoming Florida population and continue to reduce the impact that invasive species has on the Florida ecosystem.

Figure 5

INVASIVE SPECIES, SOURCE: GOOGLE IMAGES

This will be beneficial at Rosebud since it is the site of many exotic invasive species of plants. Of the 117 species identified at Rosebud, 27 of them are considered exotic invasive species. Of these 27 species, twenty of them are in the I category of the FLEPPC class. Those in category I are invasive exotics that are altering the native landscape by displacing native flora and changing ecological structures. Those in category II are those that have increased in abundance but have not altered Florida's native habitats to the extent of those in category I (Committee, 2019). Some of the most observed species in this category are Cogon grass (*Imperata cyclindrica),* Brazilian Pepper *(Schinus terebinthifolius),* Peruvian Primrosewillow *(Ludwigia peruviana),* Ceasars weed *(Urena lobata),* and Wild Taro *(Colocasia esculenta)*. Those found in Category II include Rattlebox (*Sesbania punicea)*, Guinea Grass (*Urochloa Maxima)*, and Wedelia (*Sphagneticola trilobata)* being the most abundant of the species. These species can displace many native animals from their habitats that rely on native vegetation such as Skipper Butterflies (*Hesperridae ssp.)* (Plant List). By teaching visitors to identify these species it can be a great tool of education for Rosebud and help promote their use for the biodigester. An additional benefit is that visitors will also learn of fauna species that rely on native vegetation for food and shelter. Rosebud can refer to previous successful examples of their efforts to eradicate invasive species in the area. In the first few years of the Bishops' buying the property, parts of the property, particularly near the lake, where populated by Australian pine *(Casuarina equisetifolia*). This invasive tree introduced from the South Pacific displaced many native plants. Through efforts by the community the plant was eradicated from the site where currently, it has not been able to reestablish itself.

One of the limitations to using invasive species in the biodigestion process is that these plants are made up of a fibrous, lignocellulosic material that does not currently breakdown well in the biodigester. This is a disadvantage because the most common and easily available material is made of up organic material that is incompatible with the current biodigesters at Rosebud. In order to use the invasive species in the process there needs to be a way to break down the material and one way to overcome this obstacle is to utilize enzymatic hydrolysis in the production of biogas. Enzymatic hydrolysis is the process of using strong acids to breakdown the enzymes found in fibrous and cellulose material (Kumar, 2021). In order to process cellulose, it must first be broken down into its smaller chemical components such as glucose, pentose, or hexose (Turning Waste Into Food: Cellulose Digestion, 2021). This pretreatment will allow Rosebud the ability to utilize the invasive species onsite and from the surrounding community to feed the biodigester. This will also simplify and improve the removal process for the invasive species, currently the most common methods to eliminate invasive species are biological, chemical, cultural, mechanical, physical, or prescribed burning (Control Mechanisms, 2021). Each of these methods contains its own consequences, limitations, and impacts to the environment, the ability to use these invasive species in the biodegestion process will help overcome these obstacles. A typical pretreatment starts with liquid hot water to help breakdown lignocelluloses and transform them into biofuel via biological conversion. What remains is lignin, as it is difficult to dissolve (Luo et al., 2019). While this is a great start, more investments and research need to be made into this resolution, in today's world enzymatic hydrolysis and the enzymes needed are expensive and the science is still being developed. Rosebud could utilize this theory and help press forward the impact of change.

Another recommendation is for Rosebud to explore the potential uses of some of the invasive species found on the property. Besides using them for the biodigester they can be used for medicinal uses and as the basis of some materials. Cogon grass is one of the most invasive and challenging plant to eradicate in Rosebud. This plant that originates from Southeast Asia has been used as construction material for roofs on traditional houses. The roots of the plant have been used for the treatment of ringworm, cholera, dysentery, and diarrhea. The Mizo people of India commonly juice the roots of Cogon grass to treat these illnesses (Lalthanpuii & Lalchhandama, 2018). Another plant of interest is Wedelia which has been traditionally used in many communities in South and Central America. The plant has also been incorporated into medicinal use to areas where it has been introduced, particularly in Eastern Asia. These communities have used the pant for muscle pains, swelling, reproductive pains, and cold treatments. Wedelia has been researched and shown to have antimicrobial, antioxidant, and anti-inflammatory properties mostly derived from the stem and leaves. Extensive research on the plant makes it a promising candidate for the treatment of diabetes (Balekar, Nakapheng, & Srichana, 2014). These two plants have been noted for their benefits and it will be beneficial for Rosebud to identify any potential uses for all exotic species present in the property. Exploring potential benefits can encourage their use and help with eradication efforts. This can also encourage Rosebud t market some of the uses for invasives and give them an opportunity to sell biproducts such as teas, herbal medicines, and the basis for some construction materials. In addition, using invasives high in lignocellulosic biomass for other purposes can alleviate the biodigesters which have difficulty processing the biomass.

Another recommendation we have is for Rosebud to allow students and locals an opportunity to dispose of their food waste for the use of the biodigesters. This can offer those unfamiliar with biodigesters an opportunity to learn how they can safely dispose of their food waste and how it ties into a sustainable economy. Like the invasive plants, Rosebud can offer discounts on fertilizers and biproducts from the biodigesters to those that bring in food waste. Another recommendation is that Rosebud offer local restaurants a tour of their biodigesters and offer them an opportunity to discard their waste, thus minimizing the amount of waste in landfills from the community. Educating the community will help bring awareness of the impacts waste has on our environment and offer them insights on how to become more sustainable within the community. The use of a portable biodigester can also be a great tool to educate those beyond Rosebud. A study from Cameroon led to the construction of a 200-liter portable biodigester which was taken through different communities and facilities to demonstrate how organic waste can be used as a renewable resource. Connecting devices such as gas stoves demonstrated spectators how the biproducts of the biodigester offered a clean energy source (Takala, Nguimbous-Kouoh, Biyindi, Manguelle-Dicoum, & Elizer, 2019). A proposed project would be for

Rosebud to build such a model that can be taken on campus and around the Tampa Bay area for educational purposes. The expansion of another biodigester can be implemented on USF property to offer those living on campus and opportunity to discard their food waste and produce energy for the college.

Every byproduct from the biodigester provides beneficial use, the recovered recycled manure solids (RMS) to be used as bedding for livestock. This rich bedding contains undigested fibers that prevent bacterial infections. The waste should be composted first, the high temperatures will neutralize pathogens, the co-digestion composting allows encourages a faster turnover time for bedding and is a safer practice (Leach, 2015). This biosolid bedding provides a safe end use for the remains of anaerobic digestion. At Rosebud, the goats are on a strict diet of oak leaves, their excrement can be collected, composted, and fed to the biodigester to help produce bedding for the goats. This "green bedding" is advantageous for animal comfort as the substrate is soft, non-abrasive, and readily available (Leach et al, 2015). Appropriately treating animal waste and incorporating it back into bedding is a sustainable practice that creates a circular system and prevents waste runoff. A study by the National Center for Biotechnology Information revealed cows rejected stalls with dewatered manure solids (29% DM), compared to dehydrated manure solids and sawdust (81% DM) at an equal frequency (Leach et al, 2015). Creating a bedding consistency catered to the goat's comfort level can be determined by mixing a variety of organic matter and utilizing different concentrations of various. Anaerobic digestion of livestock waste can assist agribusiness by eliminating odors, manure pathogens, and greenhouse gas emissions efficiently.

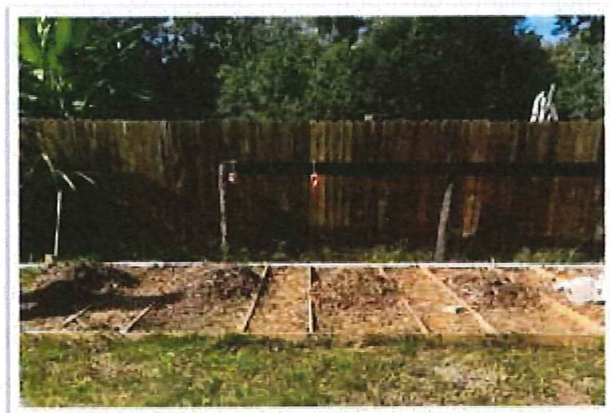


Figure 6

ROSEBUD, SOURCE: ANDRES CABRERA

Conclusion

The purpose of this project was to analyze the practices of sustainability and sustianability principals in the operation and management of these processes or services from a systems persepecitve. This project is focused on the creation of renewable engery, soil amendments, and a food source for Rosebud Continuum by using the main three on-site biodigesters and using food waste and invasive species to "feed" them to make fuel and a rich fertilizer. We focused on several different sustainability foci such as design, food, energy, and techonolgy to help create a new platform and use for already existing technology and forward looking innovation.

The idea of sustaibility or sustainable practices is to meet our own needs without compromisng the ability of future generations to meet their own needs. These practices focus on four main pillars: environmental, social, economic, and cultural. Sustainability practices and effots are not just focused on the environemental impacts that our choices as human beings have but also our our cultural, economic, and social impacts. The use of biogesters to converte food and plant waste into fuel and fertilizer can help limit our relinace on fossile fuels and help fight the effects that these fuels have on climate change. It can also provide an alternative solution to the current engery crisis, currently the world derives its energy from nuclear engery, renewable resoruces, and fossil fuels such as coal, natural gas and petrolum. Today we source approximately 80% of worlds enegery from fossil fuels, burning these fossil fuels accounted for 74% of the U.S. greenhouse gas emissions in 2019 alone (Fossil Fuels, 2021). Reducing our reliance on fossil fuels and providing an avenue to utilize biproudcts such as food waste and invasive species as fuels helps make use of "throw away" produces and reduces our alliance on unsustainable energy sources and help reduce the impact we have on climate change.

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