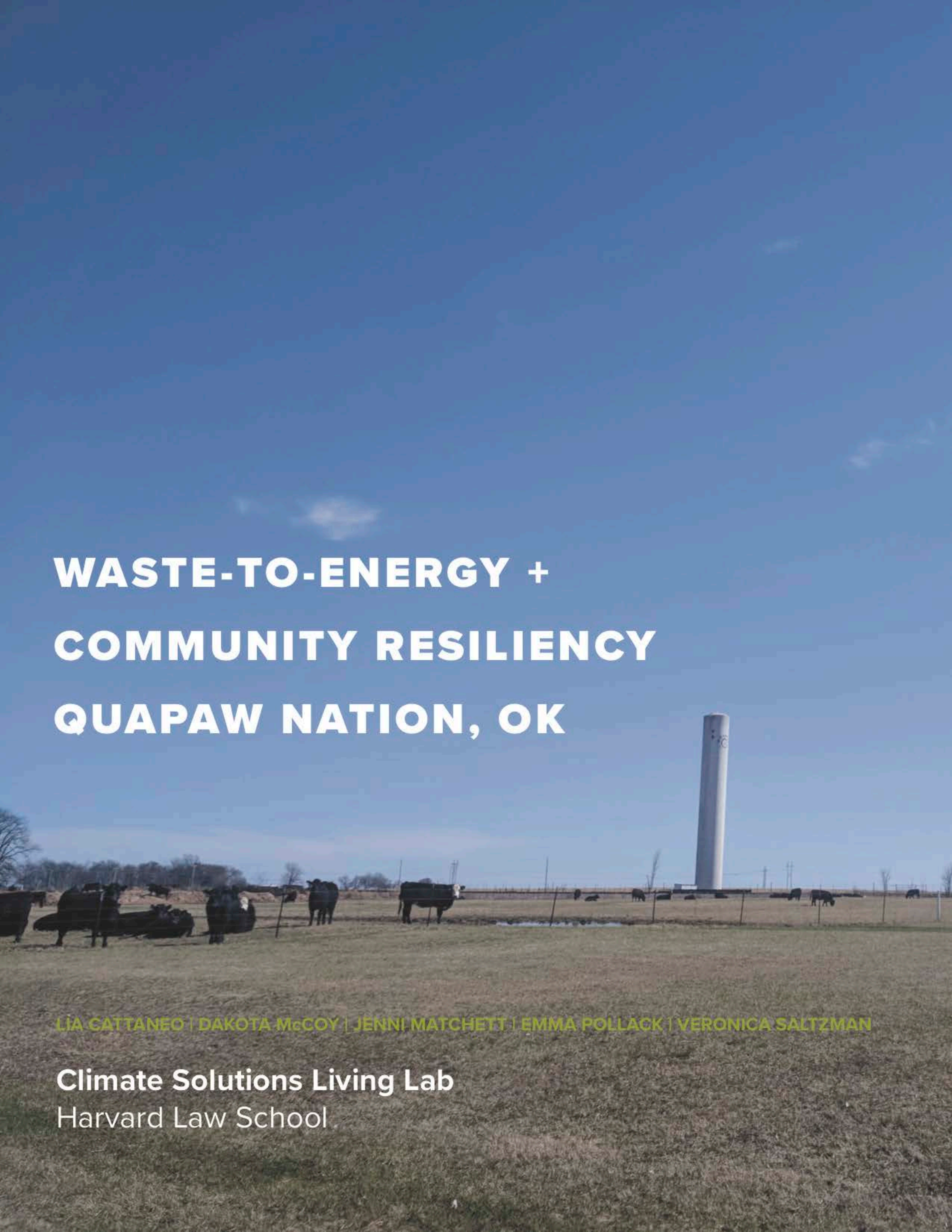

WASTE-TO-ENERGY + COMMUNITY RESILIENCY QUAPAW NATION, OK

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This Report and Implementation Plan are student work product completed to fulfill requirements of the Climate Solutions Living Lab, a 12-week course offered at Harvard Law School. This report and plan were researched and written under tight time constraints to answer specific questions posed to the students in their course assignment. Any opinions expressed in the report are those of the students and not of Harvard University or Harvard Law School. If you would like to learn more about Harvard Law School's Climate Solutions Living Lab, please contact Professor Wendy Jacobs at wjacobs@law.harvard.edu.

TABLE OF CONTENTS

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EXECUTIVE SUMMARY

The Quapaw Nation (the "Nation"), a Native American tribe in Northeast Oklahoma, has sustained and nurtured a culture of environmental stewardship, sustainability, and community-focused leadership. The Nation's land is home to the largest Superfund site in the country. In addition to leading the remediation process of lead-polluted land, the Nation demonstrates their commitment to sustainability by operating greenhouses, a sustainable brewery, and multiple farm-to-table restaurants, among other ventures. As the Nation evolves and takes on new challenges, they are exploring ways to divert their waste away from landfills in an environmentally-protective way.

Much of the Nation's organic waste is food waste from their casinos and other businesses. When food rots in a landfill, it emits methane (a greenhouse gas more potent than carbon dioxide) and pollutes the air and water. Food waste is a major problem, but it can be a significant opportunity because it is high-energy and high-nutrient-value. Anaerobic digestion, a technology that converts waste to energy, is a sustainable solution to food waste on the Nation and beyond. Anaerobic digesters consist of a large tank filled with microbes that digest organic waste. The microbes produce two useful outputs: (1) biogas (a mix of methane, carbon dioxide, and other trace gases) that can be purified and converted to electricity or heat, and (2) a high-nutrient liquid that rivals synthetic fertilizer in its nutrient content and can be used as fertilizer or as a soil amendment. In the Nation's case, electricity, heat, and fertilizer outputs can be used in existing business operations and potentially as part of Superfund remediation, all while preventing the emissions and other negative impacts of food waste.

The Quapaw Nation plans to grow its operations and develop new businesses. For example, they are currently planning a new casino in Arkansas, and they have a vision to turn the remediated Superfund land into a solar energy farm. An anaerobic digester will allow the Nation to meet its immediate food waste reuse goals, while also developing capacity within the Nation to implement future renewable energy and zero-waste projects.

PROJECT-SPECIFIC OUTCOMES

PROFITABILITY

The Nation can use a small anaerobic digester, or "microdigester," to divert waste from landfills and generate a variety of useful outputs as well as social and health benefits. The 20-year NPV of the project is $832,000 with cost savings and revenue streams generated from:

fertilizer

The digester can produce ~177,138 gallons per year of nutrient-rich digestate, which can be sold to farmers at an estimated value of $183,781/year or used to supplement the Nation's substantial compost purchases.

energy production

The digester can operate at approximately 26 kW, reducing electricity costs $24,000 per year.

waste diversion

Diverting food waste from landfills can reduce waste pickup fees by $13,140 per year.

GREENHOUSE GAS EMISSION REDUCTIONS

Greenhouse gas (GHG) emissions reductions —348 MT CO2e annually and 6,960 MT CO2e over the lifetime of the digester—would result from (1) capturing methane that would otherwise be emitted by the food waste at a landfill; (2) capturing methane that would be emitted from the septic treatment of meat processing waste; and (3) producing electricity and displacing grid-based energy

HEALTH & SOCIAL BENEFITS

Further, this project may improve air quality, soil fertility, and environmental stewardship and therefore help to improve the overall health of both the Quapaw as well as environmental justice communities associated with landfills and fossil fuel extraction.

The Quapaw are a model for resilient community leadership, and anaerobic digestion could enhance their leadership further through building capacity in waste management and renewable energy production.

$832,000
20-year NPV

177,000
gallons of fertilizer annually

348 MT CO_2e
emissions avoided annually

792 TONS
waste diverted from landfill

REPLICABILITY & SCALABILITY

As a global society, we must reduce our dependence on fossil fuels. This requires a revolutionary transition to clean and renewable energy from the individual to societal levels. Although the Quapaw Nation alone has a relatively small food waste footprint, they can be a model for similarly-sized communities to re-evaluate the concept of waste.

This project could be a template for:

1. Replicating the digester design at the Nation's own casino in Pine Bluff, Arkansas, set to begin construction in 2020;

2. Bringing in waste from other tribes and nearby businesses and building additional microdigesters to handle the added waste volume;

3. Building more micro-scale anaerobic digesters in rural areas and environmental justice communities. Currently, most microdigesters for food waste are located in cities and not in areas of highest need;

4. Building micro-scale anaerobic digesters at similarly sized institutions across the country; and

5. Demonstrating proof-of-concept for the idea that biogas can serve as a backup energy source for renewable projects, such as the Nation's potential new solar array.

The Quapaw Nation is already a proven leader in sustainability and resiliency. By building capacity in anaerobic digestion and converting waste to energy, they can continue to lead toward a green future, supporting and inspiring tribes and communities to pursue sustainable, innovative waste management strategies.

Project Goals + Background

BACKGROUND

FOOD WASTE

Forty percent of food in the United States goes uneaten[1] through losses at some point in the supply chain between production of food and the consumer. This massive amount of waste contributes to climate change, accounting for approximately 8% of global greenhouse gas emissions;[2] if it were a country, food waste would rank 3rd behind the United States and China.[3] In this assessment, we are concerned with only the subset of food waste that is plate waste (i.e., food that has been served but not eaten), spoiled food, or peels and rinds considered inedible.[4]

Nearly all food waste ends up in landfills,[5] where it makes up 22% of municipal solid waste — more than any other single material.[6] Emissions from food waste are produced as the food is decomposed. In a landfill, food waste often decomposes under anaerobic conditions, producing methane. Depending on the landfill, the gas may or may not be captured and used or flared, converting methane into less-potent carbon dioxide. Even with capture, the efficiency is relatively low.

Ideally, no food would be wasted at all. There are projects and programs aimed at reducing food waste on the front-end, such as campaigns to teach consumers about the "sell-by," "use-by," "best-by," and expiration dates on foods in the hopes that fewer people will throw away unspoiled food.[7] But in light of the amount of food that is sent to landfills and the environmental and health impacts it causes, countries, states, and cities have begun implementing solutions.

Despite these efforts and others, the food waste problem persists. There is great opportunity and need for institutions and individuals to reduce their food waste and the negative impacts of that waste. Anaerobic digestion presents a relatively inexpensive and effective solution to reducing food waste emissions, while generating useful outputs such as electricity, heat, and fertilizer.

ANAEROBIC DIGESTION

By anaerobic digestion, waste is converted into usable energy. In short, organic waste that would otherwise go to a landfill is instead placed into a tank in the company of microbes. The microbes digest the waste, in the process making byproducts: heat, biogas (methane, carbon

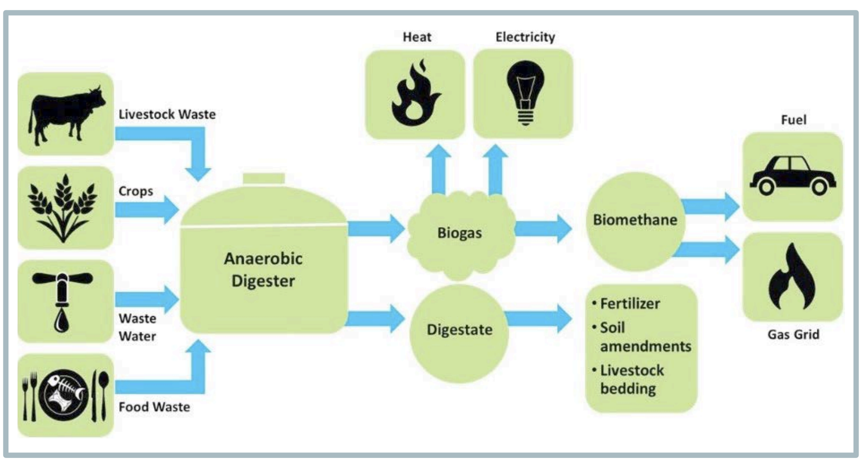


Figure 1. Schematic of an anaerobic digester. In the case of the Quapaw Nation, only food waste and some wastewater will be used as digester inputs. **Source:** Environmental and Energy Study Institute.

dioxide, and others), and nutrient-rich liquid and solid matter termed "digestate." The biogas is captured, purified, and converted to heat or power. The digestate, which is nutrient-rich, can be used as a soil amendment or fertilizer.

Unlike in landfills where methane is captured, anaerobic digesters often have (i) a smaller transportation footprint for the food waste, (ii) higher rates of gas capture (less leakage), and (iii) the gas is used for a beneficial purpose (unlike at most landfills).

QUAPAW NATION & SUSTAINABILITY GOALS

The Quapaw Nation (the "Nation") is a small, innovative, indigenous nation of 5,247 people located in northeast Oklahoma, close to the town of Joplin, Missouri. The Nation is deeply committed to sustainability in all they do, and their primary goal for this project was to develop a better, more environmentally-friendly management strategy for their food waste.

Food waste in the Nation comes mainly from the Downstream Casino Resort, a large casino with five restaurants, three bars, and two hotels totaling 374 rooms.[8] The Nation also operates a farm-to-table greenhouse, beehive, and microbrewery, and it oversees the Quapaw Cattle Company — which includes a USDA-certified organic meat processing facility — and the Quapaw Coffee Company — a coffee roastery. These other business ventures are largely sustainable but produce some waste that we have incorporated into our analysis.

Working with the Nation, we identified several overarching sustainability goals that were important in determining the outcome of project:

1.

Reduce the environmental burden of the Nation's waste, including impacts on climate change and landfill capacity

2.

Build capacity within the Nation in a resilient and sustainable manner

3.

Produce fertilizer for use in Superfund remediation

4.

Avoid adverse **health impacts** and, to the extent possible, improve health benefits

TAR CREEK

Although not the main focus of the assessment, the Nation is home to one of the worst Superfund sites in the country's history — Tar Creek. Any proposed project should consider if and how it can be of service in the clean-up process. The 40 square-mile site — covering half of the Nation's land — was once home to the largest zinc and lead mine in the world. It continues to pose risks to the surrounding communities from degraded water quality, exposure to lead dust, and mine hazards (e.g., sudden land subsidence).

The Nation is working with the Environmental Protection Agency to clean up and reclaim the land. They remove about 1 million tons of chat (i.e., remnants of lead- and zinc-laced mine waste) per year with 30 million tons remaining. Since 2015, they have remediated 350 acres of direct chat-filled land, which they plan to use for agricultural operations. To remediate the Tar Creek Superfund site, the Nation purchases mushroom compost from a nearby mushroom farm. However, they are open to producing their own nutrient-rich soil (i.e., compost or fertilizer-enriched soil).

images: A chat pile (i.e., mine tailings) from the original lead and zinc mines in Picher, Oklahoma (above, **Source**: Quapaw Nation) and a chat pile in the process of being remediated (below, **Source**: Authors).

Technical Analysis

TECHNICAL ANALYSIS

We recommend the Nation purchase a small-scale anaerobic digester, termed a "microdigester". This is a relatively new product that allows small volumes of waste to be processed in a unit the size of a shipping container. The self-contained unit can intake the Nation's waste and produce a variety of useful outputs, including biogas, heat, and digestate (which can be used as fertilizer).

TECHNOLOGY

With any digester, it is important to customize the design of the system to the inputs. Anaerobic digesters come in several types; for example, complete mix and plug flow. They must operate at a specific temperature, and inputs must be mixed properly to ensure the microbes are not "overwhelmed" by the composition of waste at any given time.

Food waste is acidic and high-energy: it presents specific requirements for optimal digestion, compared with manure digestion or garden waste digestion. To digest food waste, we recommend the following technological specifications (**Table 1)**: middle ("mesophilic") temperature of operation, two-stage complete mix digestion, an added buffer, and blending or grinding the waste before inputting it into the digester.

Given the low amount of waste available in the Quapaw Nation (see "Inputs"), we further recommend that the Nation use a microdigester designed to process less than 1,000 tons of food waste per year.

RECOMMENDED TECHNICAL SPECIFICATIONS FOR THE DIGESTER:

mesophilic temperatures
(86°F - 100° F)

Food waste is typically digested at medium temperatures,[9,10] rather than high (122°F - 140°F), in part because (i) high temperatures can cause the accumulation of ammonia and volatile fatty acids that disrupt digestion,[11] and (ii) middle temperatures foster a more diverse and stable community of microbes,[12,13] requiring less careful management.

two stage digestion

Anaerobic digestion consists of four chemical processes, each of which occurs at a different rate: by two-stage digestion, one tank performs acidogenesis and hydrolysis, and one performs acetogenesis and methanogenesis. This is flexible to changes in flow rate of waste and is an economical and efficient way to digest food waste.[14,15] However, two-stage digestion often entails a larger start-up cost and may not be available for microdigesters (small digesters suitable in size for the small amount of waste produced by the Quapaw).

complete mix

Digesters come in many types, including covered lagoon, plug flow, fixed film, and complete mix. Complete mix digesters are well-suited to food waste;[16,17] they have a large central tank (usually cylindrical), have continuous mixing during digestion, and require relatively more liquid waste than other digester types.

blend or grind waste

Blending all the solid wastes together can make the input more homogenous (thus reducing the chance that foaming occurs).[18] In general, it is recommended that post-consumer food waste be processed prior to digestion to remove impurities like metal, cardboard, plastic, and similar.[19,20]

add a buffer

cow manure or sodium bicarbonate

Food waste alone is too acidic and easy to digest for some microbes, which causes a rapid buildup of volatile fatty acids and ammonia inhibition.[21,22] Anaerobic digestion of food waste alone is unstable,[23,24,25] while co-digestion with manure or sewage sludge (i) has synergistic benefits on biogas production,[26,27] (ii) is more stable,[28,29,30] and (iii) promotes a more diverse microbial community which is therefore more robust to stress.[31]

INPUTS

The Nation is deeply committed to sustainability. For example, their greenhouses recycle waste through compost that is then used in the greenhouses. The Nation has some, but ultimately not much, organic waste. In a preliminary survey, we identified three major waste streams (**Table 1**, see Feasibility Study for more details). The waste streams are high-energy (food waste and meat production waste) as well as high-liquid-content, which makes them very suitable for anaerobic digestion. In addition to the waste sources in **Table 1**, we would expect additional food waste from many other business operations at the Nation, and grease which is currently given to a contracted grease disposal company could be input into the digester as well.

Table 1. Internal sources of organic waste in the Quapaw Nation.+

Source	Composition	Amount (approximation)
Coffee Roastery	Coffee chaff	12 tons/yr
Downstream Casino Resort	Food waste (pre- and post-consumer)	280 tons/yr
Meat Processing Plant	Liquid*: Water, meat cuttings, blood	500 tons/yr
Total Waste		792 tons / yr (4,340 lbs / day)

* Entire head is removed and US Department of Agriculture inspector inspects to ensure there is no brainstem remaining (i.e., ensures no mad cow disease entry into waterways).

+Detailed calculation methodology for this table can be found in the Feasibility Study.

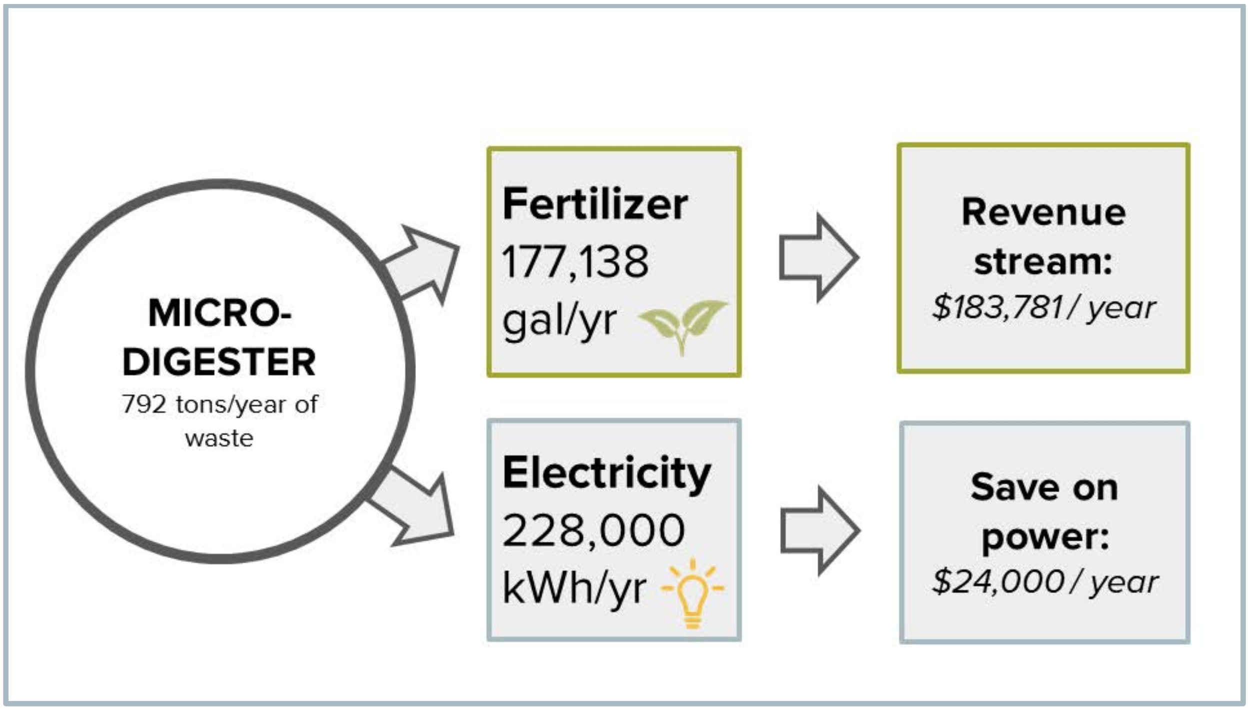


Figure 2. Diagram of digester outputs. **Source:** Authors.

OUTPUTS

Anaerobic digestion results in several outputs: heat, digestate, and biogas. The uses and transformations of these can be selected for the specific project. Digestate from food waste is nutrient-rich high-liquid matter, which can be dried into a chalk-like solid or used as a liquid. The biogas can be converted into renewable natural gas (RNG) for transportation fuel or put into an engine to generate electricity.

We recommend the Nation use the biogas to produce electricity and use the liquid fertilizer as-is without drying. The fertilizer can be sold wholesale as liquid soil amendment, used on their existing golf courses and row crops, or mixed with purchased soil and apply it to lands in the process of remediation.

1. BIOGAS

When microbes break down and consume parts of organic waste, they produce biogas. Biogas is useful because it can be processed and used to generate electricity, heat, or fuel. Biogas mainly consists of methane (CH_4; 65-75%)[32] and carbon dioxide (CO_2; 25-30%),[33] but it also contains traces of other gases (e.g., nitrogen, hydrogen, hydrogen sulfide, and water vapor) depending on the input waste materials. Hydrogen sulfide (H_2S) is a harmful element of the biogas produced, because it can damage a generator, so it should be (i) pumped through a column of desulfurizing bacteria or (ii) sent through a scrubber (e.g., iron chloride will chemically remove H_2S).[34]

According to information about microdigesters currently available, 5,000 lbs of waste per day can generate 3,258 MMBTU/yr, or approximately 30 kW in generation capacity (27.5% efficiency). For the amount of waste we estimate from the Nation (4,340 lbs/day), this can be scaled to 2,828 MMBTU/yr, or approximately 26 kW in generation capacity.

We recommend the Nation use the biogas to produce electricity for three reasons.

First, it emerged as a preference in consultation with the Nation.

Second, it can be used instead of fossil fuels to power building facilities close to the digester.

Third, the Nation is investigating a grant to build a large solar array. Biogas can be stored and used as a backup power source when the sun does not shine, providing the rare possibility of 24/7 renewable energy (rather than using fossil fuels as a backstop for renewables). By producing electricity with the biogas now, despite the small amounts available, the Nation can acquire the infrastructure and expertise to consider the biogas-as-backstop model.

2. DIGESTATE

Digestates—the other product of anaerobic digestion in addition to biogas—are the liquid and solid leftovers of microbes waste processing. Typically, digestate contains carbon and valuable nutrients such as nitrogen, phosphorus, and potassium. It can be processed and used as fertilizer, compost, soil conditioner, or animal bedding; the exact use depends on the inputs to digestion as well as the conditions of digestion. While larger ADs may produce a solid digestate that is suitable for animal bedding or compost, the microdigester produces a mostly-liquid output (~97% liquid) that can be dried passively (i.e., evaporation) or actively (i.e., heat evaporated) and used as a solid soil amendment. Liquid digestate can be stored in a large tank onsite and then delivered to remediated land plots to add nutrition back to the soil. The Nation would need to purchase topsoil and amend it with the liquid digestate in order to use the liquid digestate for Superfund remediation.

According to information about one microdigester available on the market, 5,000 lbs of waste/day can generate 204,077 gallons of liquid fertilizer per year (177,138 gal when scaled to the Nation's waste) or 850 lb dry product per month (738 when scaled to the Nation's waste) if 100% dried. We recommend the Nation use the liquid fertilizer as-is without drying; then, they can either sell it wholesale as liquid soil amendment, use it on their existing golf courses and row crops, or mix it with purchased soil and apply it to lands in the process of remediation. Food waste produces a particularly high-nutrient digestate, and thus can generate a high-value fertilizer.

Digestate produced by food waste is high-nutrient-value (**Table 2**), with high potential as a fertilizer. It should be noted that we refer to this output as fertilizer throughout the document, but there may be restrictions on the use of the word "fertilizer", since it often refers to a product with a specific nutrient content. Some companies refer to digester-based fertilizer as merely "plant food".

Table 2. Food waste generates high-nutrient content digestate, which could be useful as fertilizer. Here we report average nutrient composition of food waste digestates (whole[35,36,37,38], liquid[39,40,41], and solid[42]) adapted from Tampio et al. (2016)[43] and Tampio (2016).[44]

	Whole Digestates		Liquid Digestates		Solid Digestates
	average (n=8)	**SD**	**average (n=5)**	**SD**	**value (n=1)**
pH	8.11	0.33	6.21	2.56	-
TS (%)	25.5	30.4	6.03	6.57	14.7
VS (%TS)	50.3	27.3	75.7	8.9	82.6
C/N	6.91	5.35	14	NA	-
TKN (g/kgFM)	9.11	7.91	4.47	2.51	8
NH_4-N (g/kgFM)	3.41	1.37	1.91	1.59	3.5
NH4-N/ TKN (%)	53.3	26.3	43.8	24.4	44
P(tot) (g/kgFM)	0.33	0.27	0.39	0.29	1.5
K(tot) (g/kgFM)	2.33	0.99	1.62	0.76	2.6

pH: a measure of acidity. **TS:** total solids content as a percentage of digestate. **VS:** volatile solids content as a percentage of total solids. **C/N:** carbon to nitrogen ratio. **TKN:** Total Kjeldahl nitrogen. **NH_4-N:** ammonium nitrogen. **P(tot)** : total phosphorus. **K(tot):** total potassium.

The nutrient content and agricultural value of food waste digestate depends on the food type, but it is typically rich in plant nutrients.[45,46,47,48,49] For example, a critical element of fertilizer is the ratio of nutrients Nitrogen, Phosphorus, and Potassium (NPK ratio): digestate from commercial food waste had an NPK ratio of 4:1:5 – which is extremely similar to that of mineral fertilizer (4:1:6).[50] It is also important to note that the type of digester and specific configuration also influences digestate quality,[51] so ongoing and direct measurements of digestate is important for any new operation.

Fertilizer is valuable if it has plant-available nitrogen and a relatively low ratio between carbon and organic nitrogen, among other characteristics. Two measures of plant-available nitrogen are NH4-N concentration and NH4-N/TKN ratio.[52,53] An NH4-N/TKN ratio of more than 50% is considered a good fertilizer while lower ratios are better described as soil amendments).[54,55,56] NH4-N is one of two plant-available forms of Nitrogen (the other being NO3-N), and it is commonly produced through anaerobic digestion of food waste. Digestate with a carbon-to-nitrogen ratio below about 25 promotes N release, because it provides excess nitrogen above the demands of soil microbes,[57] and thus could serve as useful fertilizer.[58] Further, there are some benefits to nitrogen availability of using digestate in its liquid form,[59] rather than in solid form.

Phosphorus and potassium are two additional key nutrients which are preserved from food waste that has been anaerobically digested.[60] Phosphorus must be in a soluble form to be valuable as a fertilizer; typically for food waste digestate, the fraction of phosphorus that is soluble is 50-70%.[61,62] It is important to measure phosphorus solubility in digestate, through Hedley fractionation. Potassium arises from plant-based food waste and remains biochemically available at all stages (because plants do not uptake potassium into organic complex molecules), including in both the solid and liquid phase of digestate.[63]

We report average values of food waste digestate nutrients in Table 3 (details in **Appendix A Table 1**), which demonstrate that the digestate from food waste has appropriate nutrient levels to be used as a fertilizer. Indeed, fertilizer from food-waste digestate can produce comparable and even greater crop yields (e.g., by 40%[64,65, 66,67 ,68]), while others show a decrease in crop yields compared to using synthetic fertilizer;[69,70] see summary in **Appendix A Table 2**. Digestate not only provides nutrients but also enhances the microbiology of soils. Digestate can also be supplemented by typical fertilizer or otherwise treated to match nutrient demands (see discussion in[71]).

Currently, the Nation purchases mushroom compost from a local farm. Mushroom compost typically has a C/N ratio of 13:1, typically contains 1.12% nitrogen, 0.67% phosphate (phosphorous) and 1.24% potash (potassium), with a pH of 6.6.[72] These values are roughly comparable to what would result from anaerobic digestion, but as mentioned above, the digestate output depends on conditions and inputs (and must be measured *in situ*).

It is important to note that there are two potential negative consequences of producing and using digestate fertilizer: (i) eutrophication, runoff, and gaseous losses associated with any fertilizer use and (ii) impurities in the digestate, such as toxins and heavy metals. Treatment of the digestate (discussed in depth in [73,74]) can reduce runoff issues as well as optimize nutrient concentrations. Heavy metals in the food waste for urban digesters can become concentrated in the digestate and accumulate in soils after use.[75,76,77] It is important to monitor the levels of metals (.e.g, Zn, Cu, Ni) and organic contaminants (e.g., polycyclic aromatic hydrocarbons) in digestate produced by food waste.[78] Both runoff and contaminants can be assessed, monitored, and controlled in collaboration with a soil testing lab (such as the nearby Soil, Water and Forage Analytical Laboratory at Oklahoma State University).

SITE

The Quapaw Nation currently occupies a 13,000-acre (53 km^2) Quapaw tribal jurisdictional area that crosses three states: Missouri, Kansas, and Oklahoma. The majority of the Nation's operations are in the state of Oklahoma, except for the Nation's Downstream Resort & Casino — their primary revenue source —their greenhouse operations, as well as some portion of their cattle and bison grazing grounds.

Due to the complicated nature of Indian land-use, the Nation would prefer to site the digester project on Tribal Trust Land (see Legal section of Feasibility Study). The preferred site location for the digester is a former sewage lagoon located close to the Quapaw Casino and the Meat Processing Facility.
(See Figure 3)

The site is approximately 20-acres in size and is located close to 3-phase power lines (in case the Nation decides to interconnect and digester project with the grid). Furthermore, this site is easily accessible via paved roads and is located in an area with little traffic. It is situated away from residential communities, therefore reducing the potential for people raising "not in my backyard" (NIMBY) concerns.

The Nation has already been evaluating the possibility of locating solar facilities on this site. Unlike most food waste anaerobic digesters, this would also place the digester close to many nearby agricultural operations that could use the digestate fertilizer.

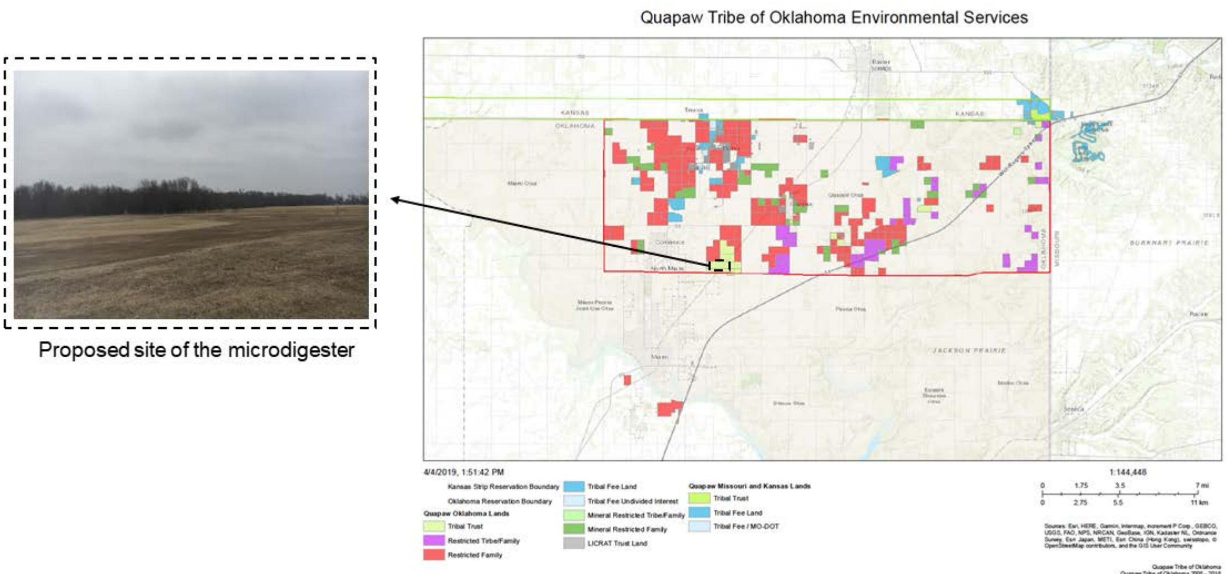
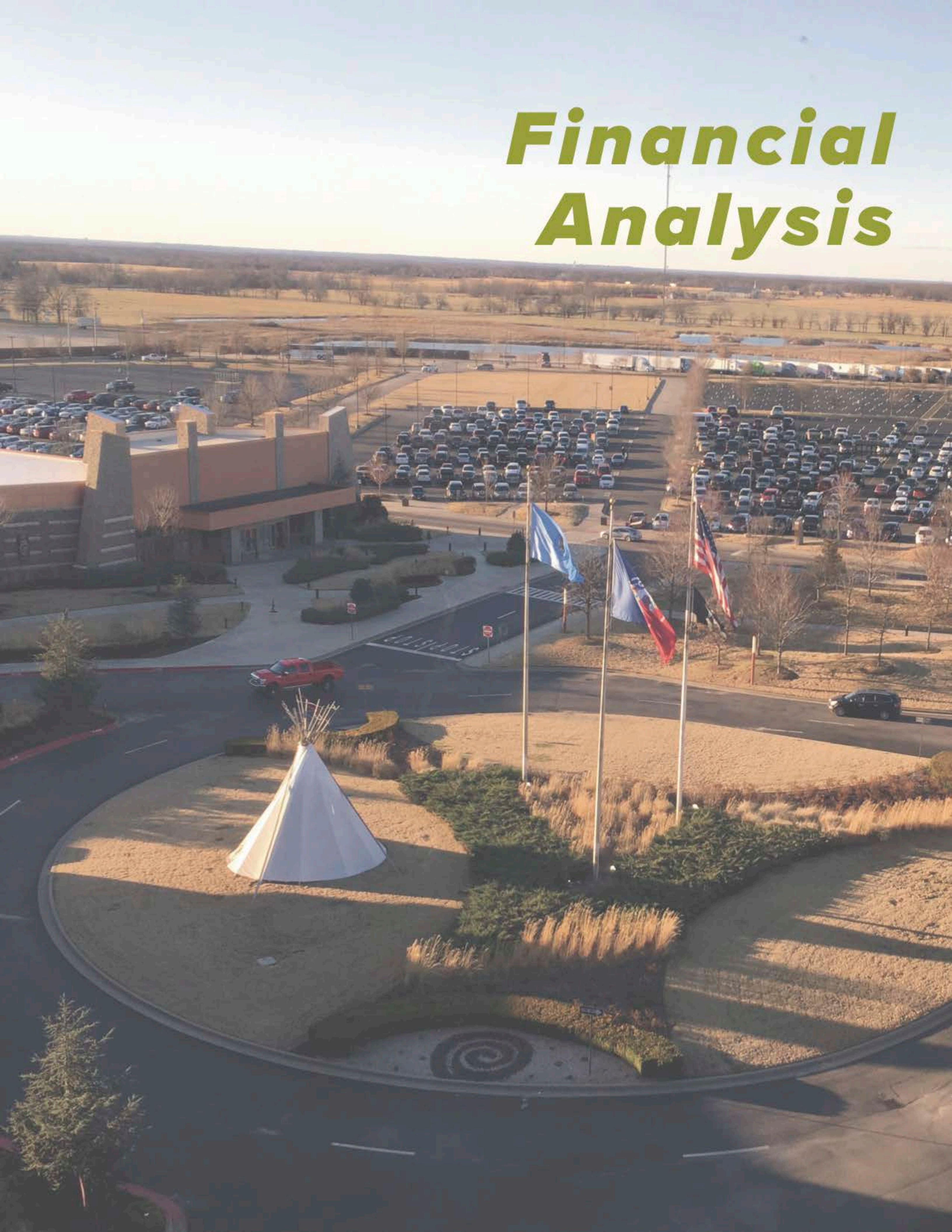


Figure 3 Proposed Site of Digester

Financial Analysis



FINANCIAL ANALYSIS

Micro anaerobic digesters, or microdigesters, present an economically-viable pathway for the Quapaw Nation to reduce their landfill impact while enhancing their cultural, environmental and social goals. The micro digester will allow the Nation to divert food waste from their casino operations and liquid waste from their meat processing operation into productive outputs such as on-site electricity as well as commercially marketable liquid fertilizer.[79]

Despite the quantifiable carbon benefits anaerobic digesters provide, the size and scale of regular digesters usually present financing challenges due to high upfront capital costs and coordination among many waste streams. In addition to these barriers, the most common scenario case studies for anaerobic digestion feasibility analysis (in the US) are happening on cattle farms across the nation.[80] Many of these farms experience significant financial challenges due to changes in the agriculture industry. The reality of these circumstances means an anaerobic digester investment must prove a financial return in a reasonable time frame in order for investment to make sense for these farms and their investors.

In contrast to these industrial agriculture operational financial needs and changing industry dynamics, the Quapaw Nation have a different set of investment return criteria, are eligible for different financial and capacity building resources due to their tribal status, and finally, are evaluating investments according to different investment time horizon parameters.[81] These circumstances create a unique set of motivators for the Nation to pursue implementation of a microdigester. Once we determined that the Nation's operations could provide waste inputs sufficient an anaerobic digester, we evaluated the economic feasibility of investing in this technology.

In order to evaluate economic feasibility, we had to answer the **following questions:**

1.

What on-site needs can the Quapaw meet with the microdigester outputs?

2.

What location will allow the microdigester to maximize avoided costs?

3.

What outputs will the micro digester produce that can potentially generate revenues?

4.

What financing options can the Quapaw access to implement this project?

The following section presents the financial feasibility and implementation summary of a deploying a microdigester at the Quapaw meat processing facility on their reservation in Oklahoma. In order to optimize the digester outputs according to the needs of the Nation, we propose that electricity produced by the digester be used at the meat processing facility and that the digestate output be converted to liquid fertilizer to either be sold externally or used by the Quapaw for their agricultural activity and potentially for remediation activities on the Tar Creek Superfund site. The recommended microdigester technology will produce 228,000 kWh of electricity per year and 177,138 gallons of liquid fertilizer per year.

SUMMARY OF COSTS & REVENUES

To evaluate the financial feasibility of the microdigester, we referenced the anaerobic digester financing model created by William Lazarus at the University of Minnesota.[82] Referencing this tool, and utilizing cost data provided by the Quapaw, we built a basic DCF model to calculate a 20-year NPV of $832,000 and a 7 year pay-back period.[83]

Table 3. Summary of financial analysis.

COSTS	
Micro digester (21 KW generator included)	$795,000 (CAPEX)
Startup Services	$20,000 (CAPEX)
Sitework	$20,000 CAPEX)
Organic waste transport	$40,000 (CAPEX)
Operations + maintenance	$47,000 (OPEX)
REVENUES / AVOIDED COSTS	
Avoided electricity cost	$24,000 / YR
Avoided waste removal cost	$13,140 / YR
Liquid fertilizer revenue	$183,781 / YR
20-year NPV (8%) **Payback Period**	**$832,000** **7 years**

FINANCIAL MODEL ASSUMPTIONS

If the Nation were to invest the full project cost and avoid costs from current waste processing operations and electricity, and if they are able to see the fertilizer output and/or use the fertilizer to offset a significant portion of their fertilizer costs, the project will generate a positive cash-flow in its first year of operation. The financial analysis will change if the Nation is able to cover a portion of the costs with guaranteed loans and/or grants provided by the federal government.

Table 4. Summary of digester inputs and outputs.

INPUTS (from Table 2)	Coffee	12 tons/year	
	Food waste (pre- and post-consumer)	280 tons/year	
	Liquid: Water, meat cuttings, blood	500 tons/year	
	Total Waste	792 tons/year (4,340 lbs/day)	
OUTPUTS	Electricity	26 kw	228,000 kWh/ year
	Liquid Fertilizer	177,138 gallons/ year	

FINANCING

The Nation's tribal status and rural geographic location make many of the Nation's projects eligible for grants and guaranteed financing at the federal level.[84]

There are a variety of funding sources for both capital expenditures, as well as other opportunities to financially support further feasibility and technical analysis that may be required to implement this project. For the goals of the Nation and the project we have recommended, we propose trying to secure funding from the US Department of Agriculture (USDA) Rural Energy for America Program (REAP) and the Tribal Energy Loan Guarantee Program.

1. RURAL ENERGY FOR AMERICA PROGRAM

The USDA Rural Energy for America Program (REAP) supports American energy independence in rural areas by supporting the private sector's development of renewable energy capacity. The program provides guaranteed loan funding to rural agricultural operations in support of the development of renewable energy systems. The program accepts applications for loans and grants on a rolling basis annually and provides a grant minimum of $2,500 and a maximum of $500,000. The funding can be put toward the capital cost of renewable energy systems, including anaerobic digesters. For projects over $200,000, applicants must also provide a feasibility study. Given the scope and scale of this project, we recommend the Nation apply for the maximum grant amount ($500,000) to cover up front capital expenditures.[85]

Table 5. Summary of available grants and loans for project finance.

PROGRAM	DESCRIPTION
Rural Energy for America Program	Guaranteed Loan Terms - $5,000 minimum loan amount - $25 million maximum loan amount Renewable Energy System Grants: - $2,500 minimum - $500,000 maximum
Tribal Energy Loan Guarantee Program	$2 billion loan guarantee for tribal energy economic opportunities

2. TRIBAL ENERGY LOAN GUARANTEE PROGRAM

The Tribal Energy Loan Guarantee Program (TELGP) is a partial loan guarantee program that supports economic opportunities to tribes through energy development projects and activities. The program can guarantee up to $2 billion in loans to support these projects. In order to be eligible for this program, applicants must be either Indian tribes or entities, or other financial institutions or tribes meeting certain criteria established by the Department of Energy. The TELGP can support a a variety of energy-related projects for tribes, including development of an anaerobic digester project.

The applications are evaluated in two phases. After the initial expression of interest passes the phase-one review, the Department of Energy will proceed with more extensive due diligence. The program accepts initial-stage applications on May 15 and July 17. The application process requires tribes to identify eligible lenders to which they apply for the required loan amount. The eligible lenders are provided a partial guarantee on the loan. Given the Nation's ambitions to develop additional renewable energy projects in the future, we think they should become familiar with this lending program and use this project as a pilot for learning to navigate the Department of Energy funding apparatus. We think they should submit an initial application to get a better understanding of the loan terms and conditions that the Department of Energy will underwrite so they can better inform future decision making about renewable energy development financing.[86]

Health + Social Benefits

HEALTH & SOCIAL BENEFITS

GREENHOUSE GAS EMISSIONS REDUCTIONS

As the climate continues to change and our emissions rise, it is critical that we incorporate mitigation efforts into routine operations, such as waste management. In order to quantify our greenhouse gas emission reductions, we looked at several pathways. **(Table 6)**

Greenhouse gas reduction benefits come from avoided emissions:

- From diverting organic waste from the landfill
- Diverting other waste disposal processes; particularly by capturing the meat processing waste which is processed in a septic tank
- From switching grid-based electricity to digester-based electricity.

We used the EPA's Waste Reduction Model (WARM) to estimate the avoided emissions from diverting wastes from existing landfill. This model generates GHG baseline and reduction estimates given information about the amount and type of waste, currently landfill specifications (e.g., landfill gas collection and fate), type of digestion (i.e., wet or dry), and distance to landfill and digester. It assumes a 25x multiplier for CH_4 relative to CO_2 in terms of global warming potential over 100 years. Electricity estimates used in the model were calculated based on grid emissions factors. More details about the calculation methodology can be found in the Feasibility Study.

Table 6. Waste sources, current practices, and opportunities for GHG emissions reduction

Source	Business as usual	GHG Savings	
		Per year ($MT\ CO_2e$)	Lifetime ($MT\ CO_2e$)*
Casino and coffee roastery	Landfilled, methane capture & flare	166	3,320
Meat processing	On-site septic treatment	73	1,460
Electricity source	Oklahoma grid: 46% gas 26% wind 24% coal	109	2,180
Reduction/year		**348**	**6,960**

* We estimated the lifetime benefits simply by multiplying the per-year emissions by the lifespan of the system, not accounting for changes in the input waste streams — though the Nation may have estimates of anticipated growth that could better inform this calculation — or changes to landfill gas collection or grid emissions intensity.

COST OF EMISSIONS

We applied the social cost of carbon (SCC) to monetize the emissions reduced from the implementation of the digester. While the SCC attempts to account for much of the environmental, health and economic impacts associated with the reduction of 1 metric ton (MT) of CO_2eit is an imperfect measurement with great variation. For the purposes of this study, we applied the Interagency Working Group from the Obama administration's valuation using a 3% discount rate: $42 in damages per MT CO_2. It should be noted that the Working Group has been disbanded under the current administration despite recognition from the scientific community of it's value and legitimacy. We have also included a sensitivity analysis to account for the range in SCC associated with the chosen discount rate (see **Table 7**).

We estimated the lifetime of the digester to be 20 years, based on conversations with experts. It should be noted that, this application of SCC assumes that the baseline emissions conditions (i.e., methane flaring at the local landfill and electrical grid composition) remain the same over this lifetime. However, Oklahoma's energy mix has shifted rapidly in the past decade as the wind sector has expanded. Furthermore, as the Quapaw explore the potential of building a solar farm on the Superfund site, the digester may cease to displace GHG emissions.

Based on these assumptions and calculations, we estimate that the implementation of the digester could save $14,616 of carbon-related damages per year or $292,000 over the course of its 20-year lifetime.

Table 7. Social Cost of Carbon (in 2007 dollars per MT CO_2e)

GHG Emissions (MT CO_2e)	Obama Administration SCC 5% Discount ($12)	Obama Administration SCC 2.5% Discount ($62)	**Obama Administration SCC 3% Discount ($42)**	Obama Administration SCC High Impact-95th percentile, 3% discount ($123)
348/year	$4,176	$21,576	**$14,616**	$42,804
6,960/ 20-year project lifetime	$83,520	$431,520	**$292,320**	$856,080

Source: Authors

HEALTH

Any systems change will have a broader impact on the health of a community and the surrounding environment. Much of health is determined by social, environmental and other external factors and therefore, it is important to complete a health impact assessment in order to ensure that the microdigester maximizes benefits and reduces risks. Our complete health impact assessment can be found in **Appendix C**.

1. PUBLIC HEALTH BENEFITS

air

By diverting organic waste from the landfill, this project would reduce CO_2 and CH_4 emissions, as well as other hazardous air pollutants. These emissions can contribute to respiratory health effects in areas surrounding the landfill, as well as in ambient air downstream of the landfill. Landfill emissions may also lead to tropospheric ozone formation, furthering cardiorespiratory impacts.

Although we do not anticipate that this microdigester will halt the extraction of fossil fuels across Oklahoma, it is important that we also consider the power that this project has in being a source of inspiration for other tribes and communities. By inviting replication, there are potential improvements in air quality associated with a shift off of the energy grid. By moving away from coal, there would be decreases in air pollutants such as PM2.5, SO_2 and NO_x, which would further improve the respiratory health of surrounding communities, as well as stress levels and occupational risks.

soil

As highlighted earlier, one of the largest outputs of the digester is the liquid nutrient-rich fertilizer. As the Quapaw Nation continues to expand its agricultural operations, there is a constant need for fertilizer, which promotes soil health and spurs the growth of healthy crops for consumption. This, in turn, can help improve nutrition within the community.

Furthermore, there is also an intense need for fertilizer in the Tar Creek Superfund remediation process. By mixing liquid fertilizer with topsoil, the Nation can further build their economy, while simultaneously cleaning up the lead-filled zones. The health impacts associated with remediation are innumerable, as lead is one of the most toxic substances to children. Remediation will also improve stress levels and reduce an environmental, social and economic burden that has been placed on the Quapaw for decades.

stewardship

The Nation has already been exemplary and inspirational in their stewardship ethos and this project just further aligns with this ethos. We believe the stewardship and environmental mission of this project will lead to improvements in mental health and education, as sustainably managing food waste can engage communities to reconnect with the land, reduce stress and incorporate environmentalism into education. Furthermore, with increased revenues and job creation, there can be reduced stress levels and improved mental health. Both personal income and Nation revenue may be invested in specific mental health services, including substance abuse programs, as well as other environmental initiatives, further maximizing the associated health benefits. Further details on the social impact is found below.

2. RISKS AND MITIGATION STRATEGIES

There are several potential risks associated with implementation of the microdigester. There are occupational hazards associated with mismanagement, as well as the risk of nutrient leaching and emission leakage. Occupational hazard can lead to injury and other health compromises. Nutrient leaching may increase water pathogens and cause eutrophication.

By properly training staff and monitoring the operations, these risks can be reduced to have minimal impact. The environmental risks may also be reduced through proper placement of the digester. This is another reason for recommending the digester to be situated near the meat-processing facility, as this area is accessible by paved road and away from residential and heavily trafficked areas.

SOCIAL

The Quapaw are committed to nurturing and sustaining a resilient social infrastructure within their community. This resilient social infrastructure is supported by three core social priorities within the Nation:

1.

Self-sufficiency, food sovereignty and an ethos of living off the land[87]

2.

Commitment to tribal member capacity building through training and job creation

3.

Re-imagining/stewarding the Tar Creek Superfund site and creating environmental opportunities

With these priorities in mind, we believe the implementation of the micro digester can support and enhance these initiatives by providing the Quapaw with the opportunity to develop renewable energy development capacity within the tribe, by creating the opportunity to develop rural waste management resources and capacity building within the tribe, and by adding another dimension to the already-robust Quapaw model for creating a sustainable and robust community

1. RENEWABLE ENERGY CAPACITY BUILDING

One of the primary opportunities the Nation would like to pursue on the remediated Tar Creek land is the development of large-scale renewable energy projects. The majority of the energy capacity on the Oklahoma grid is carbon intensive. The Tar Creek site has about 40 square miles of land for the Nation to re-imagine new uses on as they undertake the heroic effort to remediate the site. The development of large-scale solar has the potential to not only serve as a significant financial opportunity for the tribe through the sale of electricity but could also provide meaningful carbon emissions reductions for the State's electricity system. However, the development of renewable energy is not an easy process and the Nation will have to creating the resource capacity required to pursue this renewable energy vision.

The microdigester project would be the Nation's first foray into renewable energy, and we think it can serve as a catalyst for the creation of new renewable energy jobs as well as serve as the kick-start towards this broader renewable energy vision the Tribe is already contemplating. The micro digester we recommend will require at least 1 full-time equivalent (FTE) to manage the inputs, and specifically the transport of waste from the Downstream Casino the digester's location near the meat processing facility. However, in addition to the FTE required for the micro digester, we recommend the Nation create a new renewable energy management team with 1-2 FTE's who can manage the process of implementing this project as well as begin planning for the development of the future solar projects.

2. RURAL WASTE MANAGEMENT CAPACITY BUILDING

Working on this project allowed us to observe first-hand the challenges around rural-waste management as well as the Nation's appetite for finding solutions that minimize their environmental footprint and create job opportunities for their tribal members.

The Quapaw are already providing leadership and waste management stewardship within their own operations (they generate very little waste), but they also provide household trash removal services for tribal and non-tribal residents outside the Quapaw town boundaries. The trash removal dumpsters are located in the former town of Picher and have collected over 1,100 tons of waste since May 2015. The associated costs for these dumpsters exceeds $100,000. Without this service, residents living outside municipal boundaries are left to their own devices to deal with their household waste.

The micro digester presents, again, another opportunity for the Quapaw to think big around rural waste management, the scalability of the waste-to-energy model and the potential opportunity to provide waste management services to communities, tribes and other entities in the surrounding area. Implementing the Oklahoma project will require associated tribal employees to evaluate their current waste management operations and develop systems to process the inputs that will "feed" the digester.

Though the scale of the micro digester project is relatively small, it should be seen as a catalyst for what could be a larger waste-to-energy initiative. This type of initiative would create skills and training opportunities for tribal and community members which would build up knowledge capacity within the tribe about waste management. Ultimately, we see the potential for this to lead to the creation of new jobs through the identification of unforeseen economic opportunities associated with waste management. To start, we recommend the Quapaw look at replicating this micro digester technology at the new casino they are building in Arkansas,

3. CO-DESIGNING RESILIENT COMMUNITIES

Defining the social benefits associated with climate action, resiliency measures and renewable energy project development is contested terrain.[88] Since the concept of sustainability was first introduced in the Brundtland Commission report, sustainability advocates have worked to create frameworks that can pin down the ambiguities embedded in the widely accepted idea of sustainable development, that is:

> “meeting the needs of the present, **without compromising** the ability of future generations to meet their own needs.”

These ambiguities include ‘Needs’ not being defined, controversy over whose needs are prioritized and Implicit assumption that decision-makers in the **now** have an idea of what society in the **future** will need.

The dynamic nature, historic social inequities and unique cultural ecology of different geographic locales further complicates the notion that some grand sustainability framework will work “across the board”. In response to the shortcomings of universal sustainability or social impact frameworks, new strides have been made in developing custom social impact frameworks and sustainability metrics. These developments are focused on a methodological framework of co-design.[89] The co-design methodology sees that the expertise of the technical stakeholders be informed and largely directed by the unique cultural dimensions of the community that wishes to implement sustainability initiatives.

Ethics of resiliency and sustainability are embedded in what it means to be a member of the Quapaw Nation. From a long history of displacement and relocation at the hands of European explorers and eventually the Federal Government’s territorial expansion to the stewardship and responsibility this Nation has demonstrated with their approach to the Tar Creek Superfund site. When we talk about building resilient communities in the face of climate change, we should be looking to Nations, like the Quapaw, who have built, and re-built, their communities on principles of resiliency and environmental stewardship. As the challenges of climate change mount larger than ever, we see this project as an opportunity for the Quapaw Nation to contribute to the development of the social benefit co-design methodology and ultimately to the creation of new knowledge and understandings about sustainability and resiliency broadly, and social benefits from renewable energy projects, specifically.

Management Considerations

MANAGEMENT CONSIDERATIONS

Management of the digester will require input and oversight from a variety of stakeholders and can contribute meaningfully to capacity building and education in the Nation. The digester will need at least one person with expertise to manage its operations.

OPERATIONS

While some microdigesters require no operational expertise, medium-sized microdigesters typically require an operator. An operator serves several purposes. First, they must ensure high-quality food waste by removing contamination and operating the grinding equipment. Second, they must monitor and adjust the rates of pumping, the temperature, and the chemical composition of the digester. Finally, they can monitor general operation, test the gas composition of the biogas (to ensure proper scrubbing procedures are in place), and test the nutrient composition of the digestate.

Companies that sell microdigesters will generally provide ongoing maintenance consultations, but some also offer add-on maintenance agreements to provide services routinely.

In addition to operational requirements, using an anaerobic digester may require training service workers and providing the bins or other infrastructure necessary to separate food from contaminants (relevant to the casino waste streams, but not the coffee or meat processing plant waste streams). The Nation has raised this as a challenge to their workflow. We recommended a microdigester with a depackaging system, which will allow the digester to take in waste that is relatively contaminated with non-organic materials. Although waste will still need to be sorted, there is less pressure to sort perfectly when depackaging is in place.

EDUCATION

Food waste in the Nation is currently ignored or viewed as a concern for the Nation. The Nation should make an effort to use the digester as a teaching tool for food service workers, casino visitors, tribal members, and children. Training workers is an opportunity to convey the sustainability ethos, educate service workers about the anaerobic digestion process, and show them the incentive for sorting waste properly. Signage or other forms of information can be provided to guests at the casino. The Nation could host an informational session or educational workshop for tribal members and children at the local schools. The person in charge of digester operations may host a workshop for other tribal nations and entities in the area looking to start their own digesters. As described above, the Nation can also use this process to educate themselves about the renewable energy grants and loans available to tribal nation.

By shifting what we view as waste, we can have a much greater impact on the systems that we belong to and the environment that surrounds us. We see this initial food waste program as one step in reducing the footprint of the Downstream Casino. The lessons learned in this process, as well as the cost savings, may provide support for further environmental initiatives, such as the transitioning of styrofoam to reusable cups.

STAKEHOLDERS

The Nation's government is divided into several committees and departments that will need to be consulted throughout the implementation of this project. Most relevant to this project are:

The Business Committee, which is a seven-member body that oversees the government of the Nation and decides on investment opportunities like this one. The Chairman, John Berrey, was instrumental in making the connection with the Climate Solutions Living Lab. He has been a proponent of innovative projects in the past, particularly when they build expertise and capacity for the Nation.

The Environmental Department, the mission of which is "to protect human health, the environment, and the cultural heritage of the Quapaw people through applying scientific methods in understanding impacts to our natural world."[90] We worked with Craig Kreman, Assistant Environmental Director for the Quapaw Nation, throughout this process. Another Environmental Division staffer, Michelle, has been to a training on composting and is in charge of exploring this option. This division would likely oversee the operation of the digester and would be in charge of hiring and training necessary staff.

The Downstream Casino, which is home to most of the Nation's food waste, will need to be an integral partner in the operation of a digester. We worked with Lucus Setterfield, Director of Food and Beverage for the Downstream Casino Resort, throughout this process. Lucus would likely continue to be the contact for this project and would oversee implementation of waste sorting practices at the casino. Lucus has been a strong proponent of the Arkansas option, siting the digester not at Downstream, but instead at the new casino in Arkansas where waste sorting processes can more easily be built into the design of the kitchens.

The Quapaw Cattle Company, which oversees the meat processing plant, will need to be a partner in this process since the liquid waste from the cattle operations are a proposed waste source. As currently proposed, the project would require diverting waste away from the septic tank system currently in use and may require redesigning operational systems at the plant.

The Quapaw Coffee Company, which oversees the coffee roastery and associated waste, will need to be a partner in this process to ensure that organic waste from the roastery is sorted and sent to AD.

The General Counsel, who will advise the Nation on the legal issues regarding the digester. We have been working with Stephen Ward, the current General Counsel, throughout this process.

There may be opportunities to bring in waste from the Downstream Q Store/, the O-Gah-Pah Convenience Store, and the Quapaw Casino. Though the Nation did not identify these waste sources as targets for reduction, waste from these sites could easily be added. It will therefore be important to consult these managers throughout the design and implementation.

Legal Analysis

LEGAL ANALYSIS

PERMITTING

The Nation plans to put the anaerobic digester on Tribal Trust Land. As explained in the Feasibility Study, Tribal Trust Land is not within state jurisdiction. As a result, the digester will only be subject to certain federal laws and regulations. The two exception to this are that the Nation will have to follow Oklahoma public utility's rules for operating a parallel generating facility (as discussed above) and obtain licenses and registration to sell fertilizer on Oklahoma. If the Quapaw decide at a later date to only use the digester to directly heat buildings on the reservation, no local rules will apply.

Additionally, if they choose to use the fertilizer directly on the reservation instead of selling it, state law will no longer apply. Finally, the digester the Quapaw wish to construct and operate is small enough to avoid triggering most federal regulations. If, however, the Quapaw decide the expand the digester in the future, they will have to be aware of federal regulations. This permitting section will mainly focus on federal regulations that *could* apply if the Quapaw expands the digester but ultimately will not apply to a small digester. Additionally, should the Quapaw decide to operate another digester outside of Tribal Trust Land (for example, at their new casino in Arkansas), they will need to consult state and local laws regulating anaerobic digesters.

1. **FEDERAL:** AIR

40 C.F.R. 60 Subpart JJJJ sets out requirements for stationary spark ignition internal combustion engines that the Quapaw will have to adhere to (although the regulation does not require the owner/operator of the engine to acquire any specific permit). The Quapaw fall under 40 C.F.R. § 60.4230 as "Owners and operators of stationary SI ICE [stationary spark ignition internal combustion engines] that commence construction after June 12, 2006, where the stationary SI ICE are manufactured… after July 1, 2008, for engines with a maximum engine power less than 500 HP."[91] After determining that the Quapaw will qualify as an "owner and operator" under the regulation, we jump to § 60.4233: "What emission standards must I meet if I am an owner or operator of a stationary SI internal combustion engine?" Once there, the Quapaw fall under section (e), "[o]wners and operators of stationary SI ICE with a maximum engine power greater than or equal to 75 KW (100 HP)."[92] Section (e) owners and operators must comply with emission standards in **Appendix D Table 1**.

Owners and operators must comply with these emission standards "over the entire life of the engine."[93] Finally, the Quapaw must follow engine maintenance and record-keeping requirements in the regulations. 40 C.F.R. § 60.4243 gives the owner/operator the option to show compliance with one of two methods.[94][95] There is not a timeline for complying with 40 C.F.R. 60 Subpart JJJJ, because no permit is required. The Quapaw simply must make sure they remain in compliance with the emissions standards.

A small digester will not trigger New Source Review (NSR) in Title I parts C and D of the Clean Air Act (CAA), which regulates pre-construction of new and modified "major sources" of emissions.[96] While NSR will be something to keep in mind moving forward if the Quapaw decide to expand the size of their digester, most anaerobic digesters are unlikely to trigger NSR permitting.[97] Moreover, an anaerobic digester is not among designated major stationary sources under 40 C.F.R. § 52.21(b)(1)(i)(a), nor does it have the "potential to emit… 250 tons per year or more of a regulated" criteria pollutant.[98] A small digester will not trigger CAA Title V permitting, which regulates "major sources" of "air pollutants" at or above a threshold of 100 tons/year. Regulations of biomass boilers and steam generating units do not apply, as the emission levels they regulate far surpass anything the digester will generate.[99] Of course, if the Quapaw decide to build an additional digester outside of Tribal Trust Land, they must check state air regulations.

2. **FEDERAL:** WATER

Construction of a digester could trigger requirements for a construction general permit (CGP) under the National Pollutant Discharge Elimination System (NPDES) program. Indian country within the State of Oklahoma is covered under EPA's construction general permitting authority.[100] However, CGP permits are only required for constructions projects that will disturb one or more acres of land.[101] Since the Quapaw is operating a small digester, it is unlikely to disturb one acre of land, particularly if the Quapaw take precautionary steps to protect against leakage. Indeed, the digester itself may be small enough to be trucked onto the site, rather than constructed there. Of course, if the Quapaw decide to expand the size of the digester in the future, they may need to apply for a CGP.

3. **FEDERAL:** SOLID WASTE

Upon further research, it seems that the Resource Conservation and Recovery Act (RCRA), which regulates solid wastes, including any "garbage, refuse, [or] sludge from a waste treatment plant . . . including solid, liquid, semisolid, or contained gaseous material resulting from . . . agricultural operations,"[102] does not apply to tribes. RCRA––unlike other environmental statutes like the Clean Water Act––does not contain a section explaining its application to Indian tribes. The only mention of tribes in the statute is in the definition of "municipality," which includes "an Indian tribe."[103]

Under RCRA, states are primarily responsible for regulating hazardous waste disposal.[104] Yet courts have held that states cannot enforce their environmental laws on Indian reservations. For example, in *State of Washington, Dep't of Ecology v. U.S.E.P.A.*,[105] the court addressed the issue of state and federal jurisdiction over Indian reservations to enforce RCRA's hazardous waste programs. The court held that "EPA correctly interpreted RCRA in rejecting [a state's] application to regulate all hazardous waste-related activities on Indian lands."[106] Additionally, the Supreme Court has held that Congress must *expressly* intend to abrogate tribal rights.[107] RCRA contains no such provision. Thus, states cannot regulate hazardous waste disposal on tribal land. Although RCRA leaves "development and enforcement of standards . . . almost entirely to the states", EPA does not fill the resulting gap left on tribal land.[108] Indeed, EPA approves state enforcement plans but does not itself issue permits.[109]

Finally, while some federal environmental laws allow EPA to give "TAS" approvals—– i.e.Tribes approved for treatment as a state—– so that tribes can implement certain environmental regulatory programs, EPA has not made any TAS approvals for applying RCRA.[110] As a result, there appears to be a "statutory void on reservations for regulating waste disposal."[111] While this may not be positive news for Native American tribes writ large,[112] it means that the Quapaw will not need waste disposal permits. If the Quapaw decide to expand and construct an digester *outside* of their reservation (for example, in Arkansas at their new casino), they should consult requirements for owners and operators of non-municipal, non-hazardous waste disposal units.[113]

4. **LOCAL:** OKLAHOMA CORPORATION COMMISSION RULES

See "Oklahoma Corporation Commission Rules for Operating Parallel Generation Facilities" under "Contracts" for rules applicable to the Nation's use of electricity from the digester.

5. **STATE:** OKLAHOMA FERTILIZER LAWS

Fertilizer sold in the state of Oklahoma must "guarantee" that the fertilizer meets a minimum percentage of plant nutrients claimed. It is possible that the Quapaw can sell the liquid digestate from the digester as fertilizer, depending on the consistency of the nutrient content.

If the Quapaw decide to sell fertilizer produced from the digester, they will be subject to Oklahoma's fertilizer distribution laws. The sale of fertilizer is generally regulated by states, not the federal government.[114] Although Native American tribes are not ordinary subject to state laws on their reservation, distributing the fertilizer *outside the reservation* puts them within state jurisdiction for those sales. Luckily, Oklahoma laws surrounding distribution of fertilizer are relatively straightforward. Below is a brief outline of the legal requirements for distributing fertilizer in Oklahoma. The Quapaw will need to complete applications for and obtain 1) an Oklahoma fertilizer license; and 2) Oklahoma fertilizer registration.

Step 1: License Application

Oklahoma law requires a party selling fertilizer to obtain a license from the Oklahoma Department of Agriculture, Food & Forestry (from the Consumer Protection Division).[115] A first-time fertilizer license application can be completed online and found here: http://www.kellysolutions.com/OK/Fertilizer/newapplication/applynow.asp. The annual license fee is $50.[116] Also, if the Nation sells fertilizer in packages of less than thirty pounds, they will be subject to a $100 additional registration fee.[117] Sale of packages weighing over thirty pounds do not incur this additional fee. The license application includes, among other things, the name and address of the applicant and the type of fertilizer the applicant wishes to sell. Once the Quapaw submit this online application form, administrators at the Oklahoma Department of Agriculture, Food & Forestry review the application and send an email seeking payment of the $50 fee (as well as the $100 fee, if applicable). This first step takes about one week.[118]

Step 2: Registration and Labeling

Once the Department of Agriculture approves the Quapaw's license application, the Department will set the Quapaw up in the registration system, and they will receive a username and password.[119] The Quapaw must then complete the first-time fertilizer registration. Again, this step can be completed online once the Quapaw have a username and password from the Department.[120] The registration application must include the following information: 1. Brand and grade; 2. The guaranteed analysis[121]; 3. Name and address of the registrant; 4. Net weight for packaged fertilizer; and 5. Oklahoma fertilizer license number.[122]

The Quapaw will also have to upload a propose label for their fertilizer on the registration application, and the Department will have to approve the label.[123] The label must be placed on the fertilizer container and, in "clearly legible and conspicuous form," must include the following information: 1. Net weight; 2. Brand and grade; 3. Guaranteed analysis; and 4. Name and address of the registrant/licensee.[124] Fertilizer product registrations expire on June 30 of each year.[125] Overall, the registration process takes about one week.[126]

Timeline for licensing and registration: approximately two weeks.

Fees associated with licensing and registration: $50-$150.

CONTRACTS[127]

1. SALES AND MAINTENANCE AGREEMENTS BETWEEN THE NATION AND VENDOR

The parties to this agreement are the Quapaw and whichever vendor from whom they choose to purchase an anaerobic digester. The following are examples of key representations, warranties, covenants, and remedies that should appear in a service agreement between the Quapaw (the purchaser) and the vendor of the digester:

Representations: (1) the vendor complies with any relevant industry standards. For example, the vendor subjects the anaerobic digester to certain safety and testing requirements before selling to the purchaser; (2) The vendor stipulates the price of the digester and any associated equipment and maintenance beforehand; (3) The purchaser has complied with any permitting and/or regulatory requirements necessary to own and operate the anaerobic digester; (4) The purchaser has sufficient funds to pay the vendor and either pays the money upfront and agrees to a payment plan (this will depend on the flexibility and preferences of the specific vendor).

Warranties: (1) Warranty of Merchantability: under the Uniform Commercial Code (UCC), there exists an implied warranty that goods will be merchantable, meaning that, at the very least, the goods: will "pass without objection in the trade under the contract description; …are fit for the ordinary purposes for which such goods are used;… run, within the variations permitted by the agreement, of even kind, quality and quantity within each unit and among all units involved;… are adequately contained, packaged, and labeled as the agreement may require; … conform to the promise or affirmations of fact made on the container or label if any."[128] (2) The vendor will deliver the digester to the purchaser on an agreed-upon date and time; (3) the vendor will provide initial instructions and training to the purchaser.

A **separate maintenance agreement** should also stipulate that the vendor (potentially for an extra cost) agrees to 1. Provide annual tests and maintenance checks of the digester; 2. Respond with 24 hours (or some agreed-upon amount of time) to purchaser's request for maintenance assistance with the digester; 3. Provide a list of included and excluded maintenance services; and 4. Provide protocol for an after-hours maintenance emergency. Additionally, the maintenance agreement will last a certain term of months or years before requiring renewal. The agreement should also set out the mode of communication by which the purchaser may contact the vendor for a maintenance request.

Covenants: the purchaser will conduct routine tests and maintenance of the anaerobic digester in accordance with the instructions and training provided by the vendor.

Remedies: 1. Vendor agrees to refund the purchaser for defects in the product and, if necessary, to replace the digester. Refund and replacement will not apply in situations where the purchaser caused the defect by failing to follow specific instructions or training regarding the digester. 2. If the purchaser pays to vendor on a payment plan, the vendor may assess an previously agreed-upon late fee if the purchaser misses a payment deadline; 3. If the vendor fails to respond (or timely respond) to a maintenance request under the maintenance agreement, the purchaser may request a partial refund of the cost of the maintenance agreement.

2. AGREEMENT AND COORDINATION WITH UTILITY

Oklahoma Corporation Commission Rules for Operating Parallel Generation Facilities

The Oklahoma Corporation Commission ("OCC") (the public utility company in Oklahoma) sets out rules for running "parallel operation of generation facilities."[129] The rule applies to "any party (interconnected party) who wishes to operate…generation facilities in parallel with a utility…"[130] The rules define "generation facility" as "a machine or machines capable of producing capacity, energy or other electricity products."[131] The digester falls within this definition of "generation facilities." The OCC sets out several conditions to running parallel generation facilities. First, the party wishing to operate parallel generation facilities must obtain prior written approval by the utility.[132] Thus, the Quapaw will have to reach out to their electricity utility and receive this written approval. The rules stipulate that such interconnection requirements "shall be reasonable" and all costs of running parallel generation "shall be borne by the interconnecting party."[133] The OCC also requires that all agreements parallel operation be submitted to the OCC for approval prior to interconnection.[134]

Agreement with and Approval from Utility to Operate a Parallel Generation Facility

Empire Electric has a standardized Parallel Generation Application Agreement (See **Appendix D**). The parties to this agreement are the Quapaw (the "Customer Generator") and Empire Electric (the Quapaw's current utility company). Although the OCC is not an official party the agreement, the agreement must comply with OCC rules, and OCC may factor into dispute resolution. Examples of key representations, warranties, covenants, and remedies that may (or should) appear in an agreement with the utility company to allow parallel generation:

Representations: 1. The electric energy generation unit is powered by a renewable energy resource; 2. The unit is located on premises owned, operated, leased, or otherwise controlled by the Customer-Generator (the Quapaw); 3. The unit is intended primarily to offset part or all of the Customer-Generator's own electrical energy requirements; 4. the Customer-Generator warrants that the generation unit meets applicable safety, performance, interconnection, and reliable standards established by relevant governing authorities.

Warranties: 1. The Customer-Generator agrees to carry liability insurance over a certain amount of money that covers risk of liability for personal injuries and property damage arising from the generation unit; 2. The utility company agrees to supply and maintain all necessary meters and associated equipment used for billing; 3. Prior to interconnection, the utility will conduct an inspection of the interconnection equipment and notify the Customer-Generator about whether it has identified any deficiencies in the equipment; 4. Customer-Generator agrees to notify the utility prior to the initial start-up testing of the unit and the utility may send a representative to be present at the start-up test; 5. The utility will notify the Customer-Generator before entering the customer's property to make any inspections or conduct maintenance of any equipment.

Covenants: 1. The Customer-Generator will, at least once a year, conduct a test to "confirm that the net metering unit automatically ceases to energize the output…within two…seconds of being disconnected from the Company's electrical system" and will maintain records of the test results and will provide the results to Empire upon request; 2. The utility will provide a bill for net consumption of electricity to the Customer-Generator at approximately 30-day intervals; 3. Dispute resolution: disagreements between the Customer-Generator and the utility company that cannot be resolved through ordinary negotiations will be brought to the Oklahoma Corporation Commission, and the parties agree to follow OCC procedures for dispute resolution.

Remedies: 1. Customer-Generator may, at any time, terminate the agreement with 30 days prior written notice to the utility; 2. Either party may terminate the agreement with 30 days prior written notice to the other party on the basis that the other party has defaulted on any terms of the agreement, provided that the terminating party give the defaulting party a chance to cure the default; 3. In the event of termination of the agreement, the Customer-Generator will completely disconnect the generation unit from parallel operation with the utility's system.

3. LETTER OF ASSIGNMENT (WASTE DISPOSAL AGREEMENT)

Whatever party is responsible for operating and maintaining the digester (for example, the Quapaw Environmental Department) should obtain short letters of assignment from the anticipated sources of waste that will go into the digester. The sources of waste will likely be the Downstream Casino, the coffee roastery, and the meat processing facility (hereinafter, "waste providers"). While all parties seem willing to cooperate with the plan to feed waste to the digester, these parties should put their expectations in writing so ensure that 1. They maintain a steady stream of waste to the digester; and 2. To avoid any misunderstandings moving forward. This agreement, or "letter of assignment" should outline to parties plans and expectations for getting waste to the digester.

Representations: 1. Waste providers regularly produce a certain amount and type of waste; 2. The Quapaw has fulfilled any regulatory requirements associated with building and operating an anaerobic digester; and 3. The Quapaw is in the process of purchasing (or has already purchased) an anaerobic digester.

Warranties: 1. Waste providers "assign" rights to all (or part) of their waste to the parties operating the digester for a particular period of time; 2. The Quapaw will begin collecting waste from the waste providers on an agreed upon date; 3. Quapaw and waste providers agree on a method of transportation for waste; 4. Waste providers and Quapaw agree on the intervals of waste transportation.

Covenants: 1. Waste providers will institute a system to sort waste in a manner agreed upon ahead of time by both parties; 2. Parties should agree on a method of dispute resolution.

Remedies: Quapaw may want to compel specific performance of waste providers (via Quapaw courts) if waste providers fail to provide waste streams under the terms of the letter. If the Quapaw cannot compel specific performance and waste streams stop, the digester may malfunction.[135]

4. OTHER CONTRACTS

The Quapaw may have to enter into several other contracts to build and operate the digester. First, the Quapaw may need a new contract with their insurance provider. Liberty Utilities/Empire District Energy Company requires that, for generators greater than 10 kW, the Customer-Generator agree to carry "no less than one hundred thousand dollars...of liability insurance that provides for coverage of all risk of liability for personal injuries (including death) and damage to property arising out of or caused by the operation of the Customer-Generator's System."[136] As a result, the Quapaw may have to increase their general liability insurance, which will involve a new contract with their insurance provider.

Additionally, if the Quapaw decide to hire someone to operate the digester, they will need to enter into an employment agreement. Finally, if the Quapaw fund the purchase and operation of the digester through federal loans and grants, they will have to enter into loan and grant agreements.

Replicability + Scalibility

SCALABILITY & REPLICABILITY

This proposed microdigester solution to the Quapaw Nation's food waste "problem" is both scalable and replicable.

SCALABILITY

One benefit of microdigesters compared to traditional large digesters is that they can be scaled up in response to increased waste volume. From conversations with microdigester salespeople, we believe that it is relatively straightforward to build capacity by installing additional microdigesters.

In the feasibility study, we discussed other tribal nations in the region as potential partners for a large digester. However, they could serve as partners for a small digester, too. There are eight tribes in the area surrounding the Quapaw Nation. Each tribe has at least one casino that could potentially supply food waste. The Nation has strong partnerships with these tribes and could explore taking in waste from outside the Nation. This would help to reduce the environmental impacts of other nations' wastes, would establish the Quapaw as a sustainability leader in the region, and would provide a small income source from the tipping fees collected.

REPLICABILITY

This project is replicable at nearly any institution with a large volume of food waste (i.e., greater than 1,000 lbs/day).

First, the Nation could consider building an identical digester at their new casino in Pine Bluff, Arkansas. This casino, which is set to break ground in 2020, is nearly identical to the Downstream Casino, so much of this analysis can be used to replicate this project elsewhere. Stakeholders were strongly in favor of implementing the digester in Arkansas, regardless of implementation in Oklahoma.

This project is also replicable elsewhere. Given microdigesters' small footprint and low waste volume needs, these can be implemented at institutions such as hospitals, universities, sports arenas, and hotels, and can be used to offset electricity needs. Depending on an institution's, the digestate produced can be sold in liquid or dried solid form or used on-site for landscape management.

Additionally, biogas from anaerobic digestion is storable and accessible anytime. It could serve as a backstop for other renewable energy projects.

Research Gaps + Next Steps

RESEARCH GAPS & NEXT STEPS

RESEARCH GAPS

We have identified several key questions that persist and that will determine the viability of the project:

1. NUTRIENT CONTENT OF FERTILIZER:

The nutrient content of the fertilizer output will inevitably be variable based on the food waste inputs. We estimate that it will have high nitrogen, potassium, and phosphorous content based on the food waste input. However, we are unsure of the nutrient effect of the large liquid input from the meat processing facility. On one hand, the high water content may decrease the nutrient content of the fertilizer, but on the other hand, nutrient-rich meat waste may contribute to high nutrient content in the final output. We recommend the Nation determine the contents of the meat processing waste and consult with microdigester experts to determine a more precise nutrient content estimate.

2. SUPERFUND REMEDIATION:

The liquid digestate from the digester may be useful in remediation efforts. We have discussed the option of mixing liquid digestate with purchased topsoil or amending topsoil with dried digestate soil amendment. The Nation should consider where the digestate could best be used given their needs.

3. ELECTRICITY PRICES:

The electricity rates used in this analysis were based on a sample bill from the Liberty Utilities, Empire District, the Nation's energy provider. To get a more accurate estimate of energy cost-savings, actual electricity rate numbers should be used.

4. LEAKAGE:

Our conversations with microdigester companies have led us to believe that the risk of leakage from the digester is relatively small; however, there may be some risk of leakage. The Nation should

5. NON-FOOD COMPOSTABLE MATERIALS:

It is unclear whether non-food compostable materials, such as bags, plates, cups, and flatware marketed as "compostable" would break down in a microdigester. Currently, the Nation uses primarily styrofoam in their to-go materials but if in the future the Nation were to convert to more compostable materials, it would be useful to know if these can be processed in a digester.

Thinking to the future, the Nation should also consider what happens if food waste is reduced through other means such that digester input volumes are reduced significantly. This seems unlikely given current practices but could be an important thought experiment for the Nation to undertake.

NEXT STEPS

The Nation has indicated that they would like to move forward with this project.

As next steps, we suggest that the Nation:

Conduct a larger-scale **food waste audit** to double check the estimates we have made for food waste

Consult with Quapaw Cattle Company about the contents of the **meat processing waste**

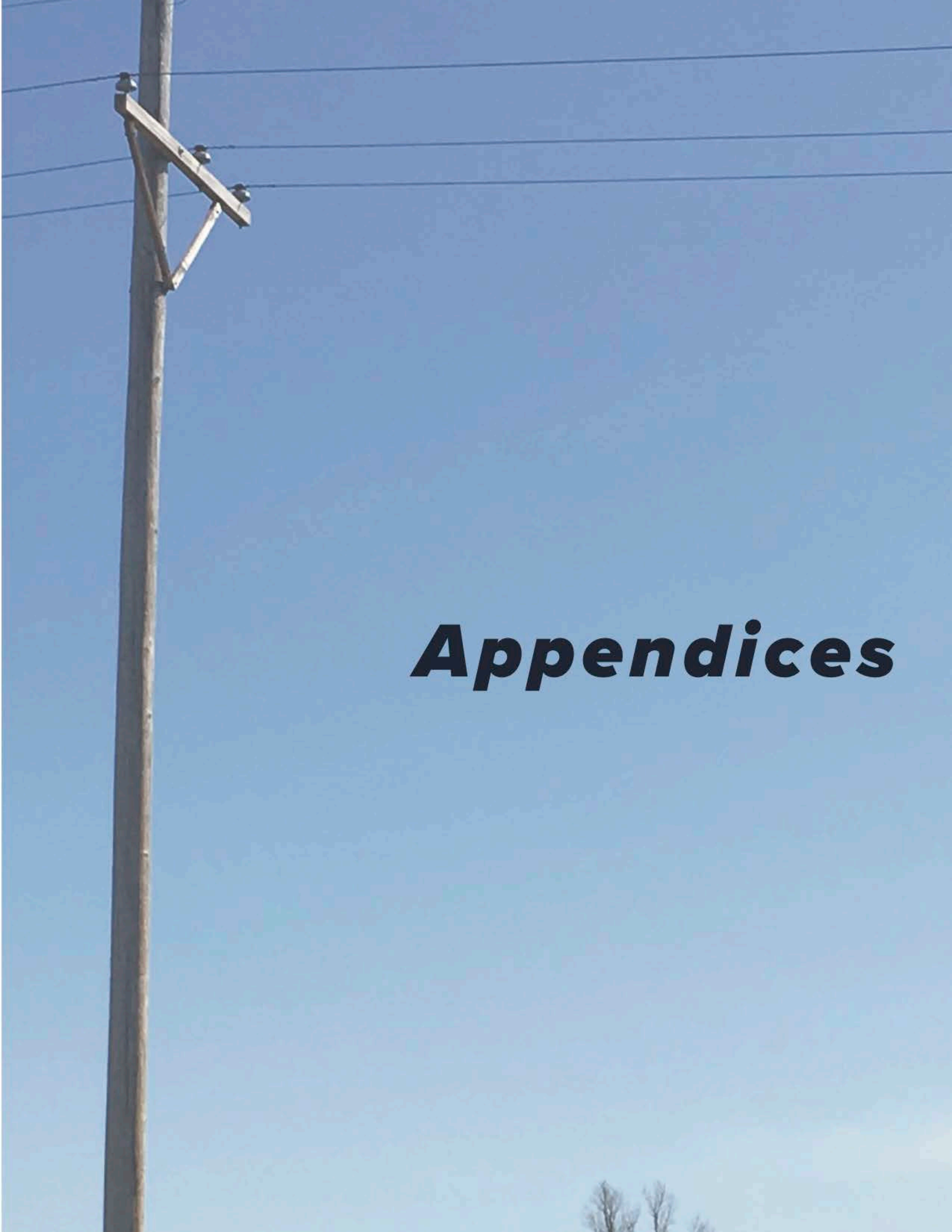
Hire an intern to manage outreach to microdigester companies and to answer the questions posed above

The intern or digester operations manager should also consult with Food and Beverage services at the Downstream Casino to discuss the process and physical changes that would be needed to **sort waste**

Reach out to **microdigester companies** to get quotes for digesters and more information about how specific technologies will work for the Nation's use case

Conduct a thorough and community-involved **health impact assessment**

We suggested the location for the digester and some specifications, but for this to actually be implemented, **engineering designs** will need to be completed that detail where exactly the digester will be located, how it will be interconnected to the meat processing plant for energy, etc.



Appendices

APPENDIX A: Fertilizer Details

Here, we present additional information about the nutrient content (**Appendix A Table 1**) and plant growth potential (**Appendix A Table 2**) of the digestate from anaerobic digestion of food waste. As with any anaerobic digester project, the specific parameters of digestion and characteristics of the waste influence the output. Therefore, we recommend careful measurement of the outputs

Appendix A Table 1. Nutrient content of digestate produced by anaerobically digesting food waste. Table adapted from Tampio (2016) and Tampio et al. (2016). References by column are A[137], B[138], C[139], D[140], E[141], F[142], G[143]

Feedstock*	pH	TS (%)	VS (%TS)	C/N	TKN (g/kgFM)	NH_4-N (g/kgFM)	NH4-N/ TKN (%)	P(tot) (g/kgFM)	K(tot) (g/kgFM)	Ref
Whole digestates										
FW	7.9–8.2	4.8–5.4	66.4–69.3	2.3–2.7	7.6–8.1	4.4–4.7	54–62	-	-	A
FW	8.3	18.4	75	15.5	28	2.0	7	0.2	-	B
60% ss-h-FW, 40% slaughterhouse waste	7.9	6.1	-	7.1	7.9	5.3	67	0.9	1.6	C
66% ss-h-FW, 24% silage, 10% grease tap sludge	8.7	5.9	-	12.1	5.3	3.3	62	0.4	3.7	C
24% ss-h-FW, 43% food processing waste, 33% slaughterhouse waste	8	1.7	-	11	2.6	2.0	77	0.2	1.1	C
ss-h-FW	8	68.1	50.2	3.3	8.7	4.5	52	0.33	3.2	D
ss-h-FW	7.6	78.8	63.7	1.5	7.8	1.7	21.3	0.19	2.5	D
ss-h-FW	8.3	19.9	12.3	2.3	4.7	3.9	82.1	0.11	1.9	D
Liquid digestates										
ss-h-FW	8.02	1.45	-		2.2	1.5	68	0.2	1.1	E
ss-h-FW		0.7	-		1.3	0.4	30	0.06	1.3	E
FW	4.4	17.1	86	14	6.0	0.5	8	0.7	0.9	F
FW+abattoir+farm waste	8.1–8.3	5.0–5.2	67.1–72.7	-	5.5–7.2	2.8–3.9	39–71	0.2–0.4	1.5–2.7	F
ss-FW	-	5.8	71.2	-	6.5	3.8	58	0.7	2.7	G
Solid digestates										
ss-FW	-	14.7	82.6	-	8.0	3.5	44	1.5	2.6	G

pH: a measure of acidity. **TS:** total solids content as a percentage of digestate. **VS:** volatile solids content as a percentage of total solids. **C/N:** carbon to nitrogen ratio. **TKN:** Total Kjeldahl nitrogen. **NH_4-N:** ammonium nitrogen. **P(tot) :** total phosphorus. **K(tot):** total potassium. *** ss** = source-segregated; **h** = household; **FW** = food waste

Appendix A Table 2. Plant growth experiments with digestate fertilization from the anaerobic digestion of food waste. Nutrient content of digestate produced by anaerobically digesting food waste. Table adapted from Table 9 of Tampio (2016) and data from Tampio et al. (2016). References are A[144], B[145], C[146], D[147], E[148],F[149], G[150], H[151].

Waste Origin	Plant/Crop	Experiment Type	Effect of Digestate Fertilization	Ref
Slaughterhouse waste + Food Waste	Spring wheat	Pot experiment	1–40% higher biomass yield compared with mineral fertilizer, lower yield compared with pig slurry	A
Food Waste+ abattoir + farm waste	Ryegrass	2-year field trial	13–23% increased dry matter yield and plant N uptake compared with mineral control, effective source of available N	B
Food Waste	Barley	Pot experiment	Equivalent grain yield with mineral NPK fertilizer	C
Food Waste	Spinach and Komatsuna	Field trial	Comparable yield and N uptake compared with mineral fertilizer	D
Food Waste	Crop rotation, barley and oats	4-year field trial	7–26% lower N yields and 19% lower crop yields compared with mineral fertilizer control. Similar crop yields were achieved with digestate supplemented with mineral fertilizerb. Digestates introduced more plant-available N and promoted soil microbial activity compared to mineral fertilizers and manure	E, F
Food Waste	Crop rotation, barley and oats	8-year field trial	15% lower biomass yield compared with mineral fertilizers. Higher yield compared with unamended and compostamended plots. Substrate induced respiration, potential ammonium oxidation, and N mineralization were improved.	G
Food waste	Italian ryegrass	Pot experiment	5-30% higher ryegrass yields compared to a control mineral fertilizer with a similar inorganic nitrogen concentration	H

Appendix A Table 3: Fertilizer Cost Assessment **Source:** Authors based on conversations with industry experts

	Amount produced	$ per gallon	% sales	Revenues
Liquid Biofertilizer Wholesale Value	44,285 gallons	$3.50	25%	$154,997.80
Per unit cost of packaging & handling		- $1.30		-$57,570.5
Liquid Biofertilizer Bulk Wholesale Value	132,854 gallons	$0.75	75%	$99,640.50
Per unit cost of packaging & handling		- $0.10		-$13,285.40
Total Value				**$183,781**

APPENDIX B: Financial Model

CAPITAL COSTS

We assume an 8% discount rate.

	Capital Cost	Operating Cost	% Total	Total
CAPEX				
Micro AD (21 kW generator included)	$795,000.00			
Startup services	$20,000.00			
Sitework	$20,000.00			
Organic waste transport	$40,000.00			
OPEX				
Labor to feed digestor		$26,730.00		
Admin + mgmt costs		$7,123.70		
Consumables + repairs		$7,920.00		
Logistics + material handling costs		$2,376.00		
Electricity cost*		$2,887.94		
TOTALS	**$875,000.00**	**$47,037.64**		-

NPV CALCULATION

CAPEX: ($875,000.00)

TOTAL PV:$1,707,212.46

NPV:$832,212.46

20-year Breakdown:

NPV	0	1	2	3	4	5
CAPEX	($875,000.00)					
Electricity		$24,000.00	$24,000.00	$24,000.00	$24,000.00	$24,000.00
Fertilizer Sales		$183,781.00	$183,781.00	$183,781.00	$183,781.00	$183,781.00
Food Waste Mgmt (avoided cost)		$13,140.00	$13,140.00	$13,140.00	$13,140.00	$13,140.00
Annual O+M		($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)
TOTAL		$173,883.36	$173,883.36	$173,883.36	$173,883.36	$173,883.36
PV		$161,003.11	$149,076.95	$138,034.22	$127,809.46	$118,342.09

NPV	6	7	8	9	10
Electricity	$24,000.00	$24,000.00	$24,000.00	$24,000.00	$24,000.00
Fertilizer Sales	$183,781.00	$183,781.00	$183,781.00	$183,781.00	$183,781.00
Food Waste Mgmt (avoided cost)	$13,140.00	$13,140.00	$13,140.00	$13,140.00	$13,140.00
Annual O+M	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)
TOTAL	$173,883.36	$173,883.36	$173,883.36	$173,883.36	$173,883.36
PV	$109,576.01	$101,459.27	$93,943.77	$86,984.97	$80,541.64

NPV	11	12	13	14	15
Electricity	$24,000.00	$24,000.00	$24,000.00	$24,000.00	$24,000.00
Fertilizer Sales	$183,781.00	$183,781.00	$183,781.00	$183,781.00	$183,781.00
Food Waste Mgmt (avoided cost)	$13,140.00	$13,140.00	$13,140.00	$13,140.00	$13,140.00
Annual O+M	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)
TOTAL	$173,883.36	$173,883.36	$173,883.36	$173,883.36	$173,883.36
PV	$74,575.59	$69,051.47	$63,936.55	$59,200.51	$54,815.29

NPV	16	17	18	19	20
Electricity	$24,000.00	$24,000.00	$24,000.00	$24,000.00	$24,000.00
Fertilizer Sales	$183,781.00	$183,781.00	$183,781.00	$183,781.00	$183,781.00
Food Waste Mgmt (avoided cost)	$13,140.00	$13,140.00	$13,140.00	$13,140.00	$13,140.00
Annual O+M	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)	($47,037.64)
TOTAL	$173,883.36	$173,883.36	$173,883.36	$173,883.36	$173,883.36
PV	$54,815.29	$50,754.90	$46,995.27	$43,514.14	$40,290.87

Conclusion:

CAPEX: ($875,000.00)

TOTAL PV:$1,707,212.46

NPV:$832,212.46

APPENDIX C: HEALTH IMPACT ASSESSMENT

EXECUTIVE SUMMARY

Nature thrives on the cycling of "waste." when a plant dies or an animal is killed, its death feeds the greater ecosystem -- it is broken down trophic level by trophic level until the billions of microorganisms feast beneath the roots of the forest. In our society, when food spoils, it enters the landfill where it anaerobically decomposes, releasing methane and other harmful pollutants into the atmosphere. Our food waste footprint is threatening the survival of not just humans, but millions of other species. At the same time that we promote a culture of wasting valuable nutrients, we depend on the extraction of fossil fuels to power our systems. This non-sustainable relationship is further threatening the survival of our environment, while simultaneously harming the health of communities. While these practices are harming humans everywhere, they are disproportionately placing the burden on vulnerable populations and environmental justice communities. Throughout this process, we asked ourselves if and how we can look to nature to improve the health of our environment and the health of our communities.

We believe that by reimagining food waste into a value-added substance, the Quapaw Nation has the potential to not only improve the health of their land and people, but to also promote a culture of sustainability and health that transcends Nations. In order to fully understand the health impacts associated with implementing an anaerobic digester, we conducted a health impact assessment in order to maximize health benefits and minimize harms. This assessment has benefited greatly from the intimate insight of the Quapaw Nation and various other stakeholders. We, therefore, recommend that before implementation a full assessment should be completed with the participation of all community members. We would also recommend that the Quapaw Nation incorporate health impact assessments into any decision-making process, particularly when designing system changes.

KEY FINDINGS

air

By diverting organic waste from the landfill, as well as inspiring a shift towards renewable energy, a microdigester can help reduce the release of greenhouse gases, as well as other harmful pollutants. This will help to improve the respiratory health of local and regional communities, particularly in more vulnerable populations.

soil

One of the largest outputs of the digester is the liquid nutrient-rich fertilizer, which can be applied to the growing agricultural operations of the Nation, as well as potentially incorporated into the Tarcreek Superfund remediation process. This application will help to improve the soil health, bolster the agricultural economy, improve food security, as well as reduce an environmental, social and economic burden that has been placed on the Quapaw for decades.

stewardship

The Nation has already been exemplary and inspirational in their stewardship ethos and this project just further aligns with this ethos. We believe the stewardship and environmental mission of this project will lead to improvements in mental health and education, as sustainably managing food waste can engage communities to reconnect with the land, reduce stress and incorporate environmentalism into education.

POTENTIAL HARMFUL CONSEQUENCES

There are a few risks associated with implementation of the digester, most notably around potential leakage, occupational risk and system failure. These risks can be greatly reduced through training and comprehensive monitoring of the system.

KEY RECOMMENDATIONS

1. **Site**: The digester should be sited away from highly trafficked areas, to reduce risks of automobile accidents and noise disturbance, and located near the meat processing facility, the intended electricity user. The site should be accessible via a paved road to reduce dust and the digester should be situated on top of a concrete surface to minimize nutrient runoff.

2. **Size:** A micro-digester should be implemented to accommodate the Nation's waste. This will build capacity at a sustainable rate with minimal disturbance to business as usual.

3. **Training:** All digester operators must participate in training on and off-site to ensure proper knowledge and management. Training of waste sorting for all food and beverage workers should also be implemented to reduce contamination of waste load

4. **Education:** Sustainability, in particular on waste management, should be included in classroom curriculum to encourage land stewardship, school compost, and waste reduction in the home.

5. **Regenerative Agriculture:** Cover crop, crop rotation, green manure, rotational grazing and other regenerative agricultural practices should be included in the field plans of the remediated land to improve soil nutrient levels, increase water retention and decrease fertilizer need and subsequent runoff.

6. **Blood Lead Level Sampling:** Blood levels should be regularly monitored for lead levels, particularly in children.

7. **Continued Research:** There are several areas for continued research including the impact of digestate application in superfund remediation, waterborne risks of digestate, contamination of digestate from food source, and the impact of aerating soil for fertilizer application.

8. **Community Participation:** Extensive engagement with all community members regarding sustainable waste management, renewable energy production, climate change, and superfund remediation to elevate public awareness and activity.

In conclusion, we have conducted this assessment to be unique to the Quapaw Nation. However, we recognize that there is tremendous value in sharing the results for broader use as anaerobic digesters and sustainable waste management practices are implemented across communities. While not every community has a toxic superfund site in its backyard, there are still hazardous waste sites, landfills and incinerators compromising the health of civilians across the globe. We have the collective power to improve these livelihoods in promoting a culture of environmental stewardship.

Assessment Characterization

In an effort to objectively compare the health impacts, an effect characterization was used. Distribution determined the geographical reach of the impact-- local (within Quapaw Nation) versus regional and beyond. Likelihood characterizes the certainty of the impact-- unlikely, possible, likely, very likely. The magnitude qualified the extent that the health effect would impact the community-- low means effects would be unnoticed or only impact very few number of people, medium would include minor changes to a larger population and high would include impacts affecting the entire population for a permanent time period.[152]

Table 1 Summary of Effect Characterization for Small Anaerobic Digester **Source:** Authors

Health Effect	Direction	Distribution	Likelihood	Magnitude
Decrease in Asthma and Respiratory Illness	Positive	Regional -- areas of landfill and energy production	Likely	Low
Decrease in Waterborne Diseases from Landfill Leakage	Positive	Regional -- areas of landfill and energy production	Likely	Low
Occupational Injury	Negative	Local	Possible	Medium
Traffic Related Injury	Negative	Local	Possible	Medium
Job Creation	Positive	Local	Very Likely	Low
Decreases in mental illness, including stress	Positive	Local	Possible	Low
Improved Economy via Ecotourism	Positive	Local	Possible	Medium
Improved Soil Fertility	Positive	Local	Possible	Medium
Superfund Remediation via Digestate- Reduced Lead Levels	Positive	Local	Possible	High
Improved Nutrition through Crop Yield Increases	Positive	Local	Unlikely	Medium

HEALTH ASSESSMENT

HIA DEFINITION

With any major systems change, there are both intended and unintended consequences. In order to fully understand the implications that these projects have on the health of the community and surrounding communities, a Health Impact Assessment (HIA) should be conducted. The HIA will provide localized insight in order to inform project planning and implementation to maximize health benefits, while minimizing health costs. The WHO defines HIA as "a means of assessing the health impacts of policies, plans and projects in diverse economic sectors using quantitative, qualitative and participatory techniques."[153]

The HIA follows a six-step structure: screening, scoping, assessment, recommendation, reporting and monitoring and evaluation. Due to time and resource constraints, a rapid assessment was completed. We recommend that a complete and detailed HIA with full participation from various stakeholder groups be completed before any construction begins. Furthermore, we recommend that a health impact assessment be incorporated into all decision-making, in order to maximize benefits and reduce risks.

Health is influenced by a wide range of determinants from individual behaviors to environmental conditions to economic, social and political factors. The WHO identifies these social determinants of health as the "the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life. These forces and systems include economic policies and systems, development agendas, social norms, social policies and political systems."[154] The health impact assessment is largely based on the idea that the majority of our health is influenced by these determinants-- forces that can be altered in both beneficial and harmful manners. By following the framework of the HIA, we can take steps toward health equity and maximum efficiency.

When analyzing the environmental and health impacts of an anaerobic digester on the Quapaw Nation, it is important to not only consider the local ecosystem, but also the larger community. For every kilowatt of energy produced and used on site, one kilowatt is being displaced from the grid. While this could mean one less kilowatt from a coal plant or one less kilowatt from a natural gas rig, we are not assuming that the size of this projected presented will shift fossil fuel production. However, when scaled and replicated, anaerobic digestion could have much greater impacts on the energy extraction system, particularly as it encourages a reimagination of what we view as waste and a behavioral shifting towards renewable energy. In addition, by rerouting waste from the landfill, this project is reducing the amount of GHG emissions and other pollutants from those areas. While these displacements may not be seen in the immediate health of the Quapaw community, they are necessary calculations to consider in the larger scope of these projects.

STEP ONE: SCREENING

The first step of the HIA process is screening. This addresses the question of whether or not an HIA should be conducted and determines the value that the assessment may have on decision-making. As noted earlier, our screening process found that the scale of this project as well as the systems involved warrant a comprehensive HIA. Furthermore, the context of the project, one situated on Quapaw Tribal Land and next to the Tar Creek Superfund site further indicate that the HIA should be performed to maximize health benefits and reduce adverse health impacts of a historically marginalized population.

STEP TWO: SCOPING

The second stage of the HIA, scoping, is used to establish a framework and plan for conducting the HIA. This is done by determining which impacts should be evaluated, as well as mapping causal pathways and methods for assessment. The population(s) affected are also identified. For this feasibility study, an overview of the baseline health status of the population living in the Quapaw Tribal County has also been reviewed.

BASELINE HEALTH ASSESSMENT[155 156]

The proposed project would be located on Quapaw Tribal Land located in Ottawa County in the Northeastern corner of Oklahoma. The Quapaw Tribal County has a population of 32,029 people (70% White, 16% American Indian /Alaska Natives [AI/AN]) with 5.9% of the population under 5 years old. Tribal enrollment is currently 5,247 members with 439 members under the age of 5 and 494 above the age of 65. The median household income for the tribal area is $37,469 for the white population and $34,762 for the AI/AN population. These incomes are lower than the state median household income levels. 20% of the white population and 22% of the AI/AN population were in poverty according to the 2009-2013 American Community Survey.[157]

In general, people living in the Quapaw Tribal Country self-identified as being in good health. According to the Behavioral Risk Factor Surveillance System (BRFSS), 79% of American Indians/Alaska Natives and 74% of whites self-reported general health as good or better.

The Nation identified several key indicators as health problems currently facing the Nation. Several cardiovascular risk factors were found-- 73% of the AI/AN population and 72% of the white population were reported to be overweight or obese and 13% of both demographics were diagnosed with coronary heart disease (compared to 8% average statewide). A growing problem in the area is diabetes which is more prevalent among the AI/AN population (25%) compared to the white population (15%).

The study also identified several respiratory health conditions. According to the BRFSS, 14% of the white population and 13% of the AI/AN population self-reported a current diagnosis of asthma. Child asthma rates were not identified, though 776 cases (9.8%) of pediatric asthma were identified in Ottawa County.[158] Chronic lower respiratory diseases (i.e. COPD) was also identified as one of the leading causes of death — the AI/AN population reported a higher age-adjusted death rate (78.3 per 100,00) than the white population (68.1 per 100,000). This rate was higher than the state average for the AI/AN population (52.6 per 100,000).

Lastly, in conversations with representatives of the Nation as well as in the community health report, several mental health conditions were identified. Most notably is the prevalence of substance abuse-- methamphetamine addiction and heavy alcohol consumption were both reported. American Indians/Alaska Natives in the Quapaw tribal area reported a higher age-adjusted death rate for suicide

(28.3 per 100,000) compared to the state rate for the AI/AN population (15.8 per 100,000). The white population also had a higher rate (24.6 per 100,000) compared to the state age-adjusted death rate (18.9 per 100,000).

One notable health factor that is missing is analysis of the blood lead levels for the both children and adults. Given the proximity of Tar Creek, a former lead and zinc mine, and the recent re-location of the town of Picher due to high blood lead levels, the impact of lead on human health, particularly in children, should be a prioritized concern. There are several air monitors installed that measure atmospheric lead levels. Atmosphere lead levels are measured by looking at a three month rolling average and compared to the National Ambient Air Quality Standards (NAAQS) which is 0.15 ug/m^3.[159] Air monitors have reported local lead levels to be typically a magnitude or two below the NAAQS. However, since lead chat is stored in stories-high piles, there are occasional spikes in lead levels on windy days (**Figure 1)**.

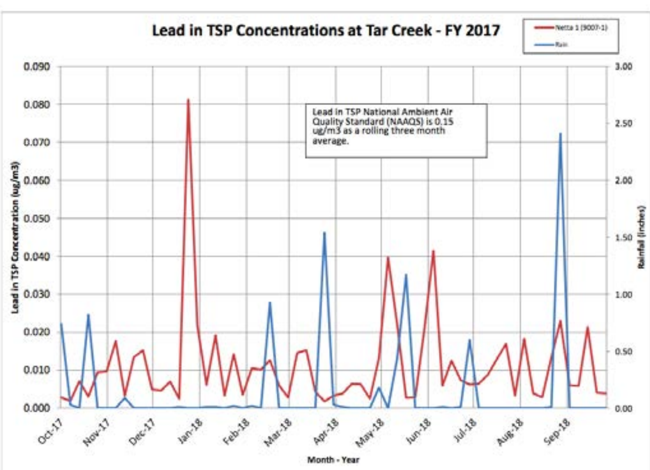


Figure 1. Atmospheric Lead Levels in Ottawa County, 2017. **Source**: Courtesy of Craig Kreman

It should be noted that these installed air monitors are measuring other criteria pollutants, including Particulate Matter (PM2.5 and PM10) and Ozone (O_3). We have not yet seen the data from these monitors but have pulled information from the 2017 EPA Air Quality Index Report for Ottawa County (**Table 2**).[160] The mean AQI was 43 placing the mean air quality as good. None of the pollutants exceeded the EPA Air Quality Standards.

Table 2. EPA Air Quality Index Report for Ottawa Country (2017)

Number of Days when Air Quality was...		Number of Days when AQI Pollutant was...	
Good	255	CO	-
Moderate	110	NO_2	-
Unhealthy for Sensitive Groups	-	O_3	145
Unhealthy	-	SO_2	-
Very Unhealthy	-	PM2.5	219
		PM10	1

During the second trip to the site, we sampled soil located near the Quapaw Pow Wow grounds. Our CSLL colleague, Martin Wolf, tested the soil for lead levels using a Laser Mass Spectrometer, comparing the Quapaw soil to a control sample pulled from MIT grounds. While the sample does not determine the exact level of lead, the comparison between the two samples concludes that Quapaw soil has much higher detector signals for lead than the sample from MIT **(Figure 2).** Based on this, we make the conclusion that the lead levels in Quapaw soil are much higher in proportion to those of MIT soil. It should also be highlighted that the Quapaw sample was drawn from an area which is not marked for remediation. Wind and weather have caused lead chat to spread across the Quapaw land, posing risks in areas where no clean-up action will be directed.

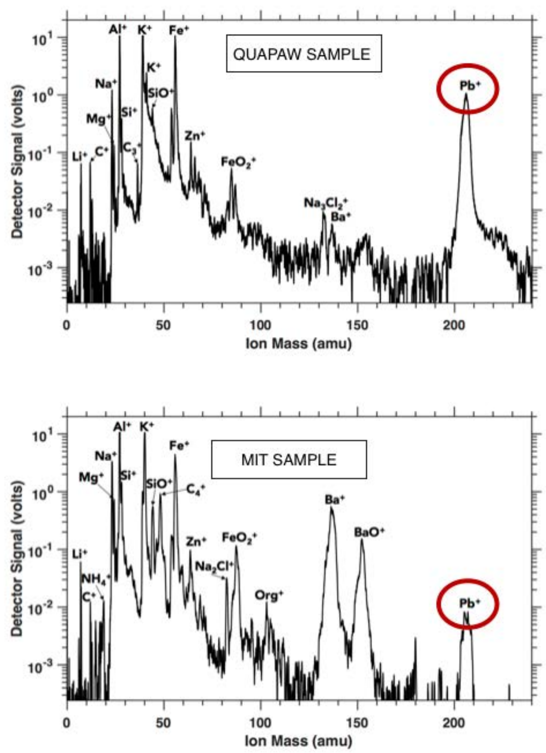


Figure 2 Heavy metals detector signals from Quapaw Soil (upper graph) and MIT soil (lower graph). **Source:** Courtesy of Martin Wolf

PATHWAYS OF IMPACT

During the scoping phase, three main pathways of impact were identified— waste diversion, fertilizer production and energy production/displacement. These pathways are explained in greater detail below.

Waste Diversion

First, with any of the three projects, organic waste would be diverted from the landfill. In our analysis, we are assuming that the current waste from the Quapaw Reservation is being carted by Republic Services to Oak Grove Landfill where methane and CO_2 are captured but flared on site. While we do not know the current landfill operations for potential waste-stream of the larger AD project, we assume that landfills are practicing similar protocol and flaring the captured gases. According to the IPCC guidelines and other studies, landfill gas capture efficiencies range greatly and on average only capture roughly 20-25% of emissions.[161,162] However, as mentioned earlier, the EPA estimates this efficiency to be 75% on average.[163] By diverting organic waste from the landfill, this project would reduce the CO_2 and CH_4 emissions. Anaerobic digestion still emits varying levels of emissions of CO_2, CH_4, as well as N_2O — however, when managed properly, these emissions are much lower than if left in landfill.[164] In addition to air emissions, landfill operations can impact local water systems through leachate. This may not only impact ecosystem health but lead to increased water-borne diseases.[165]

Fertilizer Production

In displacing food waste from the landfill, anaerobic digestion utilizes the captured nutrients to produce fertilizers. This beneficial output has potential use in both growing spaces on the Quapaw Land (greenhouses and row crops), as well as in the Tar Creek remediation process. Locally, fertilizer production can improve soil health, therefore increasing crop yields and potentially improving nutrition levels of consumers. Regionally, by producing fertilizer on site, there could be a displacement of synthetically produced N_2 fertilizer. While both the digestate and the synthetic fertilizer admit N2O through field application, most synthetic fertilizers originate from fossil fuels and include large emissions during the production period.[166] Life Cycle Assessments show that roughly 50% of

GHG emissions come from the production stage of synthetic fertilizer. Furthermore, by producing fertilizer on site, the emissions associated with transportation would drastically decrease, as distance from source to soil would be much smaller.

The Nation has stated that the fertilizer used for the remediation is primarily compost purchased from the mushroom farm. This mushroom farm is located across the street from the suggested site of the digester, therefore rendering the change in transportation distances negligible. Regardless, by producing a fertilizer onsite, the Nation would not only save costs, but could also sell the digestate to the EPA remediation process or other entities. This increased revenue could be invested in both health and environmental programs.

Energy Production / Displacement

While the capacity of energy production differs based on the size of the digester, there is the opportunity to displace some electricity or heat from the grid. The impact of these cost-savings, as well as the improvement in energy security, may result in social and economic benefits to the Nation. While we do not see either anaerobic digester as having a large impact on the grid, the potential for scalability could result in greater disturbances to the energy portfolio of Oklahoma. Currently, the energy mix for Oklahoma is 46% natural gas, 24% coal and 26% renewables, though these numbers are quickly shifting as Oklahoma takes advantage of its wind potential.[167] [168] The Quapaw AD aligns with this transitioning grid and may serve as a model and driving force in furthering this shift.

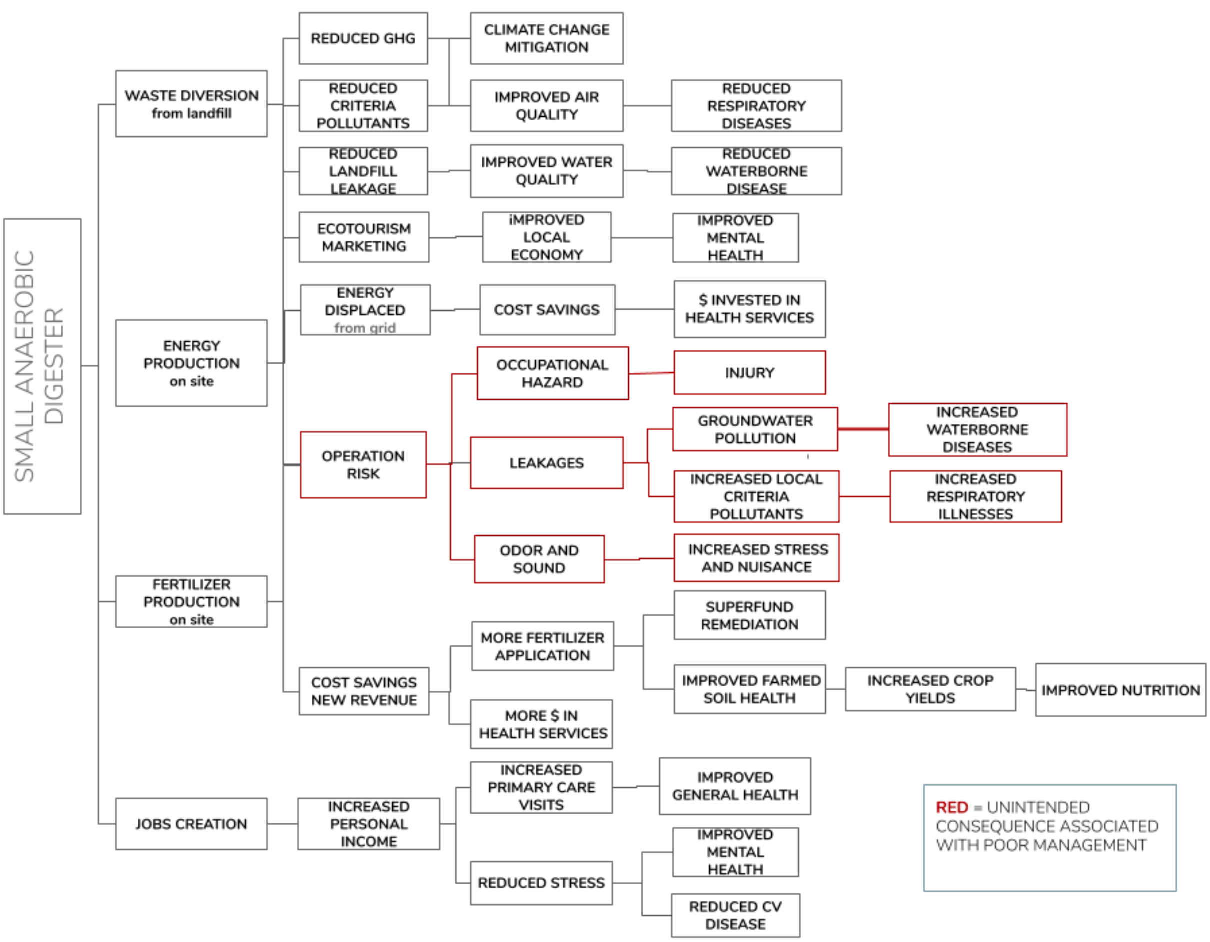


Figure 4. Causal Framework For Microdigester **Source:** Authors

STEP THREE: ASSESSMENT

The third step is the assessment. An overview of the baseline health status of the population living in the Quapaw Tribal County is included, as well as the qualification and quantification of various health pathways and impacts.

AIR QUALITY

Given the proximity of Tar Creek, air quality is monitored closely on the tribal land and it is important to consider the potential impacts that the digester would have on air pollution. Potential pathways for air pollution will come from construction, vehicle emissions, traffic-related dust as well as direct emissions from the digester. The likelihood of these impacts vary with management practices, but it is assumed that the magnitude of the overall impact is not severe. If scaled, however, there is the potential for greater air quality benefits due to the reduction of criteria pollutants (particularly PM and NO_X) associated with reduced fossil fuel extraction as well as the reduction of emissions associated with landfill operations.[169, 170]

The increased presence of vehicles may impact air quality through elevated levels of NO_X, PM, CO, and O_3.[171] The magnitude of the impact is unlikely to be very high. The health effects of each pollutant are described in **Table 3.** Most notable are the impacts of these pollutants on the respiratory system. As noted earlier, asthma, COPD and other respiratory symptoms are already prevalent in the region and thus increased air pollution can aggravate already existing symptoms and illnesses.

Table 3. Health Effects Associated with EPA Criteria Pollutants **Source**: Authors, adapted from EPA[172] and Cabin Creek HIA[173]

Pollutant	Source	Health Effects
Carbon Monoxide (CO)	Vehicle Exhaust, Fossil Fuel Burning Machinery, Wood Burning Stoves, Leaking Furnaces	Dizziness, confusion, reduced oxygen delivery to heart, cardiovascular diseases, death
Ozone (O_3)	Vehicle exhaust. Power plants. Tropospheric ozone formed in reaction of NOX and VOC with sunlight	Coughing, throat irritation, chest pain, worsened asthma, reduced lung function
Particulate Matter (PM)	Dust, construction, smokestacks, power plants and diesel engines	Increased haze, decreased lung function, aggravated asthma, cardiovascular effects, eye irritation
Nitrogen Oxides (NO_X)	Vehicle emissions, power plants, fuel burning	Respiratory symptoms (coughing, difficulty breathing), asthma, precursor to PM and ozone

Another potential air quality impact comes from the actual production. If anaerobic digesters are not managed properly, there is the potential for methane leakage from the AD as well as odor release. In addition to impacting climate change, methane is a precursor to tropospheric ozone production which can impact human respiratory systems, as well as the productivity of crops.[174] Nitrous oxide is also associated with ozone depletion and could therefore cause populations to be more vulnerable to cancer-causing UV rays.[175] It is also important to note that biogas contains trace amounts of H_2S, PM, CO_2, moisture and ammonia.[176]

Recommendation

Although on-site air emissions may not be significant, there could be a reduction in adverse health effects by strategically locating the operations away from populated areas. This may reduce the health impacts associated with vehicle emissions and potential operational mismanagement. With biogas conditioning systems including scrubbers to remove the trace contaminants, particularly H_2S, the likelihood of harmful impact is greatly reduced.

Benefit Potential

As noted above, diverting waste from landfills will reduce production of landfill gas (LFG), which is composed primarily of methane and carbon dioxide, with trace amounts of non-methane organic compounds (NMOCS) including hazardous air pollutants and volatile organic compounds.[177] These emissions can contribute to health effects in areas surrounding the landfill, as well as in ambient downstream of the landfill. Landfill emissions may also lead to tropospheric ozone formation, furthering cardiorespiratory impacts.

Similarly, it is important to include an assessment of the potential pollutants reduced through a change in the energy grid. We used the EPA's AVERT model to estimate the reductions of these emissions.[178] As the AVERT model does not include an anaerobic digestion option, our calculations account only for energy efficiency and not for the emissions from the digester. Similar to the previous table, this model assumes that the grid of Oklahoma remains constant over the lifetime of the digester. Accounting for these assumptions, the implementation of the microdigester would save a yearly 8 lbs of PM2.5, 136 lbs of SO2, and 82 lbs of NOx. Reductions in these pollutants may improve the respiratory health of the surrounding communities, particularly in children and elderly. (**See Table 3**)

In addition to the costs associated with every ton of CO2 emitted, we have included an analysis of the costs of other pollutant emissions, particularly PM 2.5, SO2, and NOX. We used the EASIUR model to identify the marginal social costs associated with emissions reduction. (**See Table 4)**

Table 4: Social Cost of Pollutants
Source: Authors

	PM 2.5	SO2	NOx --
Emissions Reduced (lbs)	8	136	82
Average Cost Per Metric Ton	$73,850	$16,925	$5,688
Savings of Emissions Per Year	$295.40	$237	$63
Savings Per Emissions Over 20 Years	$5,908	$4,740	$1,260

GREENHOUSE GAS (GHG) EMISSIONS

The primary way in which GHG emissions are reduced through these programs is by waste diversion. There is also the potential to disrupt the grid and shift energy extraction away from fossil fuels. While this is not assumed to be a direct impact of these specific digesters, there is potential for a domino effect and regional trend towards biogas production based on the success of the Quapaw program.

Reductions in GHG emissions impact human, environmental and animal health in more ways than most can imagine. By reducing air pollution, millions of premature deaths can be prevented globally.[179] Similarly, by mitigating climate change, there will be dozens of health benefits. Climate change is exasperating some of the greatest public health threats we are facing today. Extreme weather, rising sea levels, population displacement, increased temperature, food and water insecurity, and vector-borne disease migration are just some of the currently identified ways that global warming is impacting our local and global communities.[180,181] Climate change impacts communicable and non-communicable diseases and contributes to millions of premature deaths. By reducing GHG emissions, even those produced off-site, this project will help mitigate climate change and reduce the associated adverse health impacts.

In the effort of monetizing the emissions reduced from the implementation of the digester, we applied the social cost of carbon (SCC). While the SCC attempts to account for much of the environmental, health and economic impacts associated with the reduction of 1 ton of CO_2, it is an imperfect measurement with great variation.[182] For the purposes of this study, we applied the Obama administration's valuation using a 3% discount rate. For every 1 metric ton of CO2 emitted, an estimated $42 of damages are associated. We have also included a sensitivity analysis to account for the range in SCC associated with the chosen discount rate. **(Table 5)**

It should be noted that, this application of SCC assumes that the baseline emissions conditions (i.e. methane flaring at the landfill and electrical grid composition) remain the same. However, Oklahoma's energy grid has been rapidly shifting in the past decade, as the wind sector is expanding. Furthermore, as the Quapaw explore the potential of building a solar farm on the remediated land, the digester may cease to displace GHG emissions.

Table 5: Social Cost of CO_2 (in 2007 dollars per metric ton CO2e) **Source:** Authors

GHG Emissions (Metric Ton)	Obama SCC 5% Discount ($12)	Obama SCC 2.5% Discount ($62)	**Obama SCC 3% Discount ($42)**	Obama SCC High Impact-95th percentile, 3% discount ($123)
348/year	$4,176	$21,576	**$14,616**	$42,804
6,960/ lifetime	$83,520	$431,520	**$292,320**	$856,080

TRAFFIC

During the construction of the AD, there will be an increased number of trucks. While the small AD project does not anticipate significant increases in traffic associated with daily operation, there will be a slight shift in traffic patterns. This may lead to increased dust particles, noise creation, vehicle emissions as well as traffic accidents. Emissions from these vehicles may lead to air pollution, including the EPA's criteria pollutants including carbon monoxide (CO), ozone (O_3), particulate matter (PM) and nitrogen oxides (NO_X).[183] The health effects of these pollutants were described earlier (**Table 3)** It should be emphasized that NOX is a precursor to ground level ozone and in addition to the respiratory impact of smog, there are potential adverse social and mental effects as well. There are also potential injuries associated with an increase in vehicles on the road, placing both drivers and pedestrians at risk. This is particularly true of larger vehicles such as the anticipated waste-hauling trucks.

Recommendation

Traffic-related health risks may be reduced through strategic site placement away from populated areas, as well as organized schedules for delivery loads and road maintenance (including visible signage).

ODOR AND NOISE

With proper management, none of the three systems should produce many odors. However, when operations are not closely monitored, there is a risk of foul odor seeping from the digester or compost pile. Odor exposure usually causes discomfort, but if excessive, may lead to coughing and respiratory irritation.[184] If odors are excessive than it may lead to social stigmatization, as well as drops in tourist numbers. This could impact the economy of the Quapaw land.

Noise pollution may be a result of construction, operation of equipment and the increased presence of trucks. Excess noise pollution may heighten stress levels, reduce sleep times and impact mental health to the surrounding communities. Occasionally, if extreme, noise pollution can cause hearing loss.[185] Similar to odor, noise may also impact the tourism in the area.

Recommendation

While odor and noise from operations have social and health impacts, they can mostly be reduced if managed properly. Siting the operation away from residential areas, as well as engaging in early conversations with community members will reduce the potential adverse effects.

WATER QUALITY

As mentioned previously, landfilling of organic materials can have detrimental impacts on the watershed. Leaching from landfill can cause nutrient runoff and eutrophication, threatening the habitats of ecosystems while also presenting health risk threats.[186] There is a risk of water-borne diseases as well as water toxicity. By diverting food waste from the landfill, there is the potential for improved water quality. However, Life Cycle Analyses have found that anaerobic digestion may also impact eutrophication and ecotoxicity.[187] This environmental impact could result in waterborne diseases and pathogens, as well as higher nitrate levels in drinking water. Nitrate ingestion is particularly harmful to children and associated with methemoglobinemia, or "blue baby" disease.[188]

The digester will also utilize wastewater from the meat processing facility. This wastewater is currently filtered through a passive system to reduce the environmental impact on the surrounding ecosystem, although trace contaminants may still exist. By utilizing this water in the digester, environmental contamination can be further reduced and thus health benefits may be maximized.

Recommendations

With proper management, there are minimal impacts on the water table with anaerobic digestion. Liquid effluent from the digester must be stored properly to reduce leakage, as well as any backup biogas stocks. Monitoring is particularly important in reducing any leakage and there should be a protocol put into place in the event of leakage.

OCCUPATIONAL RISK

There are many risks associated with operating anaerobic digesters — there is a risk of explosion, gas leakage, toxicity and asphyxiation, as well as injury associated with handling equipment.[189] While these risks are unlikely, it is still important that they are recognized.

Recommendations

It is important that workers are properly trained in all operations and risk management. It is also critical that the facility is properly designed, as well as routinely inspected to minimize occupational risks.

JOB CREATION

Job creation is often associated with improved economic security and reduced stress levels. As income is one social determinant of health, a wide range of health benefits may be seen with the creation of new positions. Employed individuals are also more likely to seek primary care than those unemployed, thus taking a preventative approach to health.

Through the implementation of the digester, we anticipate at least one new job to be created. This position would be responsible for managing the operations of the digester, as well as facilitating between the waste producers (Downstream Casino) and output users (Meat Processing Plant and fertilizer recipients). Beyond just providing an income, this job would provide technical skill application, a sense of responsibility, and serve as potential inspiration to younger generations to engage in environmental work.

Recommendations

It is critical that proper training is included for each position in order to reduce any occupational risk. Funding should be provided in order for this individual to attend seminars, workshops and additional trainings throughout the period in which they are holding this position.

MENTAL HEALTH

This project strives to promote capacity building and improve mental health by creating jobs, building community and improving environmental accessibility. With increased revenues and job creation, there can be reduced stress levels and improved mental health. Income may be invested in specific mental health services, including substance abuse programs. As noted before, potential odor and noise pollution may increase stress levels and negatively impact mental health. It is again stressed that community collaboration and proper management is implemented to reduce these adverse effects.

SOIL FERTILITY

As highlighted earlier, one of the largest outputs of the digester is the liquid nutrient-rich fertilizer. As the Quapaw Nation continues to expand its agricultural operations, there is a constant need for fertilizer. The digestate could either be sprayed on crops, mixed with topsoil for a bulkier application, or used on the golf course located adjacent to the Downstream Casino. By promoting soil health and spurring the growth of healthy crops for consumption, the digester could help to improve yields and therefore improve food security, as well as the agriculture economy.

Furthermore, there is an intense need for fertilizer in the Tar Creek Superfund remediation process. By mixing liquid fertilizer with topsoil, the Nation can further build their economy, while simultaneously cleaning up the lead-filled zones. The health impacts associated with remediation are innumerable, as lead is one of the most toxic substances to children. Remediation will also improve stress levels and reduce an environmental, social and economic burden that has been placed on the Quapaw for decades.

> by **reimagining food waste** into a value-added substance, the Quapaw Nation has the potential to not only improve the **health of their land** and people, but to also promote a **culture of sustainability** and health that transcends Nations.

Recommendations

As noted earlier, there may be risks of trace contaminants in the digestate -- it is therefore critical that the digestate is monitored and tested on a regular basis to reduce risk. Although fertilizer is important in improving soil fertility and expanding agricultural development, we recognize that the overuse of fertilizer, whether it is digestate, compost or synthetic, can lead to nutrient runoff, eutrophication, and downstream health effects, particularly through water. We therefore recommend that the use of digestate is integrated into the efforts of promoting regenerative agriculture in order to reduce nutrient runoff, sequester carbon, and shift the global industry's reliance on synthetic fertilizer.

ENVIRONMENTAL STEWARDSHIP

The Nation has already been exemplary and inspirational in their stewardship ethos and this project just further aligns with this ethos. In addition to implementing an organic waste collection program in the casino, outreach programs may collaborate with the local school to include classroom compost and environmental education. We believe the stewardship and environmental mission of this project will lead to improvements in mental health and education, as sustainably managing food waste can engage communities to reconnect with the land, reduce stress and incorporate environmentalism into education. Furthermore, with increased revenues and job creation, there can be reduced stress levels and improved mental health. Both personal income and Nation revenue may be invested in specific mental health services, including substance abuse programs, as well as other environmental initiatives, further maximizing the associated health benefits.

STEP FOUR: RECOMMENDATIONS

The fourth step of the HIA is recommending efforts to maximize benefits and mitigate harm. The HIA has been instrumental in informing key decisions for this implementation plan, from the size of the digester to the site of operation and the use of the outputs. Recommendations have been mentioned throughout this report.

STEP FIVE: REPORTING

It is recommended that this HIA and implementation plan is not only reported to the decision makers of the Quapaw Nation, but also shared with the larger community for public comment. The true strength of an HIA rests in its ability to contextualize impacts in specific populations and it is therefore critical that community members are consulted and included in this process. We recommend various stakeholder meetings, as well as surveys and public outreach to educate members on the potentials of sustainable waste management and renewable energy production. This may have broader implications beyond the scope of one microdigester and it will also encourage further civic engagement. Lastly, through effective and comprehensive reporting, the HIA may be adjusted to better maximize benefits, reduce risks, reach community goals and build capacity.

STEP SIX: MONITORING AND EVALUATION-

As the final step in the HIA, it is important that protocols are set into place for monitoring and evaluating the progress of this project. There are several areas that should be monitored and evaluated over the lifetime of the digester.

First, it is important to assess the leakage and associated impacts from the digester. This will allow for improvements in the operations and reduction in harm. Protocols should be designed in anticipation of leakage.

Second, output usage and efficiency should be monitored, particularly in relation to displacement of current energy and fertilizer sources.

Third, community surveys should be utilized over specified time periods to evaluate the impact of the digester on mental health, environmental stewardship, behavioral change, and capacity building. This will also provide useful information for other climate and environment programs within the Nation.

Through effective monitoring and evaluation, we can assess whether benefits were maximized and risks reduced, as well as account for any consequences not captured in this HIA. Lastly, monitoring and evaluation will provide details on whether the recommendations were effective, as well as areas in which further research should be considered. This will help inform future HIAs conducted by the Nation, as well as other communities.

Appendix D: LEGAL

§ 60.4243 What are my compliance requirements if I am an owner or operator of a stationary SI internal combustion engine?

[...]

(b) If you are an owner or operator of a stationary SI internal combustion engine and must comply with the emission standards specified in § 60.4233(d) or (e), you must demonstrate compliance according to one of the methods specified in paragraphs (b)(1) and (2) of this section.
(1) Purchasing an engine certified according to procedures specified in this subpart, for the same model year and demonstrating compliance according to one of the methods specified in paragraph (a) of this section.
(2) Purchasing a non-certified engine and demonstrating compliance with the emission standards specified in § 60.4233(d) or (e) and according to the requirements specified in § 60.4244, as applicable, and according to paragraphs (b)(2)(i) and (ii) of this section.
(i) If you are an owner or operator of a stationary SI internal combustion engine greater than 25 HP and less than or equal to 500 HP, you must keep a maintenance plan and records of conducted maintenance and must, to the extent practicable, maintain and operate the engine in a manner consistent with good air pollution control practice for minimizing emissions. In addition, you must conduct an initial performance test to demonstrate compliance.
(ii) If you are an owner or operator of a stationary SI internal combustion engine greater than 500 HP, you must keep a maintenance plan and records of conducted maintenance and must, to the extent practicable, maintain and operate the engine in a manner consistent with good air pollution control practice for minimizing emissions. In addition, you must conduct an initial performance test and conduct subsequent performance testing every 8,760 hours or 3 years, whichever comes first, thereafter to demonstrate compliance.

Table 1. Table 1 to Subpart JJJJ of Part 60—NO_X, CO, and VOC Emission Standards for Stationary Non-Emergency SI Engines ≥100 HP (Except Gasoline and Rich Burn LPG), Stationary SI Landfill/Digester Gas Engines, and Stationary Emergency Engines >25 HP. *Source*: 40 C.F.R. § Pt. 60, Subpt. JJJJ, Tbl. 1.

Engine type and fuel	Maximum engine power	Manufacture date	Emission standards [a]					
			g/HP-hr			ppmvd at 15% O_2		
			NO_X	CO	VOC [d]	NO_X	CO	VOC [d]
Non-Emergency SI Natural Gas [b] and Non-Emergency SI Lean Burn LPG [b]	100≤HP<500	7/1/2008	2.0	4.0	1.0	160	540	86
		1/1/2011	1.0	2.0	0.7	82	270	60
Non-Emergency SI Lean Burn Natural Gas and LPG	500≤HP<1,350	1/1/2008	2.0	4.0	1.0	160	540	86
		7/1/2010	1.0	2.0	0.7	82	270	60
Non-Emergency SI Natural Gas and Non-Emergency SI Lean Burn LPG (except lean burn 500≤HP<1,350)	HP≥500	7/1/2007	2.0	4.0	1.0	160	540	86
	HP≥500	7/1/2010	1.0	2.0	0.7	82	270	60
Landfill/Digester Gas (except lean burn 500≤HP<1,350)	HP<500	7/1/2008	3.0	5.0	1.0	220	610	80
		1/1/2011	2.0	5.0	1.0	150	610	80
	HP≥500	7/1/2007	3.0	5.0	1.0	220	610	80
		7/1/2010	2.0	5.0	1.0	150	610	80
Landfill/Digester Gas Lean Burn	500≤HP<1,350	1/1/2008	3.0	5.0	1.0	220	610	80
		7/1/2010	2.0	5.0	1.0	150	610	80
Emergency	25<HP<130	1/1/2009	[c] 10	387	N/A	N/A	N/A	N/A
	HP≥130		2.0	4.0	1.0	160	540	86

PARALLEL GENERATION AGREEMENT EXAMPLE[190]

LIBERTY UTILITIES/THE EMPIRE DISTRICT ELECTRIC COMPANY
APPLICATION /AGREEMENT FOR PARALLEL GENERATION SYSTEMS
WITH GENERATING CAPACITY OF OVER 100KW

AVAILABILITY:

Electric service is available at points on the Liberty Utilities/The Empire District Electric Company (The Company) the Company's existing distribution facilities located within its service area for customers operating renewable fuel source generators.

.

The parallel generation service shall be available to Customer-Generators on a first-come, first-serve basis until the total rated generating capacity of net metering systems equals 5% of the Company's single-hour peak load during the previous year. Resale electric service will not be supplied under this schedule.

DEFINITIONS:

Customer-Generator:

The owner or operator of a qualified electric energy generation unit that meets all of the following criteria:

a. Is powered by a renewable energy resource;
b. Has an electrical generating system with a capacity of more than one hundred kilowatts
c. Is located on a premises owned, operated, leased, or otherwise controlled by the Customer-Generator;
d. Is interconnected and operated in parallel phase and synchronization with the Company;
e. Is intended primarily to offset part or all of the Customer-Generator's own electrical energy requirements;
f. Meets all applicable safety, performance, interconnection, and reliability standards established by the National Electrical Code, the National Electrical Safety Code, the Institute of Electrical and Electronic Engineers and any local governing authorities; and
g. Contains a mechanism that automatically disables the unit and interrupts the flow of electricity back onto the Company's electricity lines in the event that the service to the Customer-Generator is interrupted.

Renewable Energy Resources:

Electrical energy produced from wind, solar thermal sources, hydroelectric sources, photovoltaic cells and panels, fuel cells using hydrogen produced by ones of the above-named electrical energy sources, and other sources of energy that become available, and are certified as renewable by the Missouri Department of Natural Resources or the Missouri Department of Economic Development's Division of Energy.

CHARACTER OF SERVICE:

Alternating current, 60 cycles, at the voltage and phase of the Company's established secondary distribution system serving the Customer-Generator's premise.

BILLING AND PAYMENT:

The Company shall render a bill for net consumption at approximately 30-day intervals based on the Company's regular tariff schedules as on file with the Missouri Public Service Commission. Net consumption is defined as the kWh supplied by the Company to the Customer-Generator minus kWh supplied by the Customer-Generator and returned to the Company's grid during the billing month. Any net consumption shall be valued monthly as follows

BILLING AND PAYMENT (continued):

To the extent the net consumption is positive (i.e. Customer-Generator took more kWh from the Company during the month than Customer-Generator produced), the eligible Customer-Generator will be billed in accordance with the Customer-Generator's otherwise applicable standard rate for Customer Charges, Demand Charges, and Energy Charges (for the net consumption).

To the extent the net consumption is negative (i.e. Customer-Generator produced more kWh during the month than the Company supplied), the Customer-Generator will be credited in accordance with the Company's bi-annually calculated avoided fuel cost of the net energy (kWh) delivered to the Company. With the exception of the Energy Charge, all other applicable standard rate charges shall apply.

PURCHASED RATE:

During the term of this agreement the Customer will receive the Company's periodically updated avoided cost for any excess generated kWh. The avoided cost is published within the Company's Schedule CP as filed with the Missouri Public Service Commission.

The Summer Season will be the four months of June through September, and the Winter Season will be the eight months of October through May.

To the extent the net consumption is zero (i.e. Customer-Generator produced the same kWh during the month as supplied by the Company), the Customer-Generator will be Minimum billed in accordance with the eligible Customer-Generator's otherwise applicable standard rate.

TERMS AND CONDITIONS:

1. The Company will supply, own and maintain all necessary meters and associated equipment utilized for billing. If the Company's metering equipment at the Customer Generator's premise does not have the capability of measuring both the net energy produced and the net energy consumed, the Customer shall reimburse the Company for the cost to purchase and install sufficient metering. In addition, and for purposes of monitoring Customer generation and load, the Company may install at its expense, load research metering. The Customer shall supply, at no expense to the Company, a suitable location for meters and associated equipment used for billing and for load research. Such equipment shall be accessible at all times to Company personnel.
2. The Company shall have the right to require the Customer, at certain times and as electric operating conditions warrant, to limit the production of electrical energy from the generating facility to an amount no greater than the load at the Customer's facility of which the generating facility is a part.
3. The Customer shall furnish, install, operate and maintain in good order and repair without cost to the Company such relays, locks and seals, breakers, automatic synchronizers, disconnecting devices, and other control and protective devices as required by the NEC, NESC, IEEE or UL as being required as suitable for the operation of the generator in parallel with the Company's system.
4. The disconnect switch shall be under the exclusive control of the Company. The manual switch must have the capability to be locked out by Company personnel to isolate the Company's facilities in the event of an electrical outage on the Company's transmission and distribution facilities serving the Customer. This isolating devise shall also serve as a means of isolation for the Customer's equipment during any customer maintenance activities, routine outages or emergencies. The Company shall give notice to the Customer before a manual switch is locked or an isolating device is used, if possible; and otherwise shall give notice as soon as practicable after locking or isolating the Customer's facilities.
5. The Customer may be required to reimburse the Company for any equipment or facilities required solely as a result of the installation by the Customer of generation in parallel with the Company's Service. This requirement is limited to equipment or facilities installed by the Company in excess of those required of the Company by the NEC, NESC, IEEE or UL.
6. The Customer shall notify the Company prior to the initial energizing and start-up testing of the Customer-owned generator, and the Company shall have the right to have a representative present at said test.

TERMS AND CONDITIONS (continued):

1. If harmonics, voltage fluctuations, or other disruptive problems on the utility's system are directly attributable to the operation of the Customer's system, such program(s) shall be corrected at the Customer's expense.
2. No Customer's generating system shall damage the Company's system or equipment or present an undue hazard to Company personnel.
3. The Company requires an Interconnection Application/Agreement (see copy below) for conditions related to technical and safety aspects of parallel generation.
4. Service is subject to the Company's Rules and Regulations on file with the Missouri Public Service Commission and any subsequently approved and in effect during the term of this service.

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[94] See Appendix D for more details.

[95] 40 C.F.R. § 60.4243(b).

[96] New Source Review refers to regulations for new stationary sources under parts C and D of the Clean Air Act. The permits resulting from NSR are the Prevention of Significant Deterioration (PSD), Minor New Source Review (Minor NSR), and/or Nonattainment Area Permits (NAA).

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[99] For example, final Air Toxics Standards for Industrial, Commercial, and Institutional Boilers at Area Source Facilities. EPA, 2011, requires biomass boilers over 10 million Btu/hr for 876 or more hours per year to meet emission standards).

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[101] 2017 Construction General Permit (CGP), 1.1.2 "Eligibility Requirements," at 1. *Available at* https://www.epa.gov/sites/production/files/2017-06/documents/2017_cgp_final_permit_508.pdf. *See also* https://www.epa.gov/sites/production/files/2017-07/documents/cgp_flow_chart_do_i_need_a_permit2.pdf.

[102] RCRA Subtitle D, § 1004(22).

[103] RCRA Subtitle D, § 1004(13).

[104] *See* 42 U.S.C.A. § 6926. *See also* Jana L. Walker Kevin Gover, *Commercial Solid and Hazardous Waste Disposal Projects on Indian Lands*, 10 Yale J. on Reg. 229, 237–38 (1993) (outlining process by which states regulate hazardous waste under RCRA)

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[106] *Id*. at 1472.

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[109] *Id*.

[110] *See* "Tribes approved for treatment as a State," Environmental Protection Agency, *https://www.epa.gov/tribal/tribes-approved-treatment-state-tas*

[111] Walker & Gover, Commercial Solid and Hazardous Waste Disposal Projects on Indian Lands, at 238-39.

[112] *See* SELECT COMMITTEE ON INDIAN AFFAIRS, WORKSHOP ON SOLID WASTE DISPOSAL ON INDIAN LANDS, S.REP. NO. 370, 102d Cong., 2d Sess. 3 (1992) (finding that "only 2 of 108 tribal landfills complied with EPA requirements"). *See also* A. Cassidy Sehgal, *Indian Tribal Sovereignty and Waste Disposal Regulation*, 5 Fordham Envtl. L.J. 431, 432–33 (1994).

[113] *See* 40 C.F.R. § 257.5. Disposal standards for owners/operators of non-municipal non-hazardous waste disposal units that receive Very Small Quantity Generator (VSQG) waste.

[114] *See* "Fertilizers Regulation," https://www.tsgconsulting.com/geography/fertilizers-regulation/.

[115] Okla. Stat. Ann. title. 2, § 8-77.5. Registration--Licenses--Fees--Penalties.

[116] Okla. Stat. Ann. title. 2, § 8-77.5.

[117] Okla. Stat. Ann. title. 2, § 8-77.5(F)(1).

[118] Call with Lance Kunneman, Program Administrator, Consumer Protection Services, OK Department of Agriculture, Food & Forestry. Lance was extremely helpful in walking through the process and provided his contact information in case there were further questions. On file with Team 2; *see also* http://www.aapfco.org/board.html.

[119] *Id*.

[120]*See* http://www.ag.ok.gov/cps/fertilizer.htm; https://www.kellysolutions.com/erenewals/login.aspx?ReturnUrl=/erenewals/Fertilizer/default_newreg.aspx.

[121] Under the Oklahoma Fertilizer Act, "'Guaranteed analysis' means the minimum percentage of plant nutrients claimed in the following order and form"; Total Nitrogen (N); Available Phosphate (P2O5); Soluble Potash (K2O). Moreover, "when any plant nutrients, substances, or compounds are guaranteed, they shall be subject to inspection and analysis." Okla. Stat. Ann. title. 2, § 8-77.3(13).

[122] Okla. Stat. Ann. title. 2, § 8-77.5(H).

[123] Okla. Stat. Ann. title. 2, § 8-77.6.

[124] *Id*.

[125] Okla. Stat. Ann. title. 2, § 8-77.5(F)(2).

[126] Call with Lance Kunneman.

[127] Quapaw Code Title 32 "Tribal Contracts" states that the title is "reserved for future legislation." Currently, there are no rules under this title. As a result, this section will discuss general contract requirements. If the Quapaw pass legislation pertaining to tribal contracts, such legislation should be consulted when drafting the discussed contracts.

[128] UCC § 2-314. Implied Warranty: Merchantability; Usage of Trade.

[129] Oklahoma Administrative Code, 165:35-29-2. Parallel operation of generation facilities.

[130] *Id*. at 165:35-29-2(a).

[131] Oklahoma Administrative Code, 165:35-1-2. Definitions.

[132] 165:35-29-2(b).

[133] *Id*. at 2(c).

[134] *Id*. at 2(e).

[135] *Cf.* Restatement (Second) of Contracts, § 359 "Effect of Adequacy of Damages" (specific performance ordinarily not ordered if damages would be adequate to protect the injured party); Alan Schwartz, *The Case for Specific Performance*, 89 Yale L.J. 271, 272 (1979) ("Under current law, courts grant specific performance when they perceive that damages will be inadequate compensation").

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FEASIBILITY STUDY
QUAPAW NATION FOOD WASTE

CLIMATE SOLUTIONS LIVING LAB
Lia Cattaneo, Jenni Matchett, Cody McCoy, Emma Pollack, Veronica Saltzman
MARCH 2019

Table of Contents

EXECUTIVE SUMMARY

The Quapaw Nation (the "Nation"), a Native American tribe in Northeast Oklahoma, is exploring ways of disposing their organic waste in an environmentally-protective way and have asked us to develop a feasibility study evaluating possible options. We considered anaerobic digestion and compost.

The existing waste streams identified within the Nation (i.e., food waste from the Downstream Casino Resort, liquid waste from a meat processing facility, and solid waste from a coffee roastery) are not enough to power a large traditional anaerobic digester (AD). Choosing this option would require the Nation to contract with many outside waste sources, increasing the logistical, financial, and legal challenges. However, it would provide a significant amount of compost, energy, and heat that could be used to offset the Nation's energy costs and costs to clean up a Superfund site on their land. It would also significantly reduce greenhouse gas emissions. Although the potential benefits of a large digester are significant, the associated risks and challenges may outweigh these benefits.

There are several microdigesters newly available on the market that would suit the Nation's existing waste volumes, while reducing costs and logistical hurdles. This option would not produce as much fertilizer as the large AD, nor as many greenhouse gas benefits. On the other hand, the technology gives the Nation some flexibility to start with a small waste stream and take in larger quantities of waste over time.

The Nation also requested we consider composting as an option for the casino and coffee roastery wastes. We did not fully evaluate composting in this study, though conclude that while inexpensive and relatively simple to implement, composting would have minimal carbon benefits.

After assessing the feasibility of the three different options, we recommended that the Nation move forward with an implementation plan for the small digester and consider how this plan could also inform the design of a new Quapaw casino in Pine Bluff, Arkansas.

1. BACKGROUND

The Quapaw Nation (the "Nation") is a small, innovative, indigenous nation of 5,247 people located in northeast Oklahoma. They are exploring ways of disposing waste from the Nation's operations in an environmentally-protective way and have asked us to develop a feasibility study evaluating possible options. Waste streams identified within the Nation include food waste from the Downstream Casino Resort, liquid waste from a meat processing facility, and solid waste from a coffee roastery.

The Nation is also in the planning and design phase for a new casino in Pine Bluff, Arkansas, that will be nearly identical to the Downstream Casino. They have suggested that this feasibility study could inform their food waste management at the new casino.

We were asked to primarily consider the feasibility of an anaerobic digester (AD). Anaerobic digestion is the process by which organic materials are degraded in the absence of oxygen to produce methane (CH_4), a combustible gas, and other nutrient-rich byproducts. The gas produced is often referred to as biogas. This process is an attractive way to manage organic waste since it can reduce harmful greenhouse gas emissions and provide energy, heat, fertilizer, and more — far greater benefits than landfilling or other traditional waste disposal methods. We also touch on the possibility of compost in lieu of anaerobic digestion; this is a similar, but largely-aerobic, process with no gas capture that results in nutrient-rich fertilizer output.

OPTIONS CONSIDERED

We considered three options for managing the Nation's waste:

(1) A small digester with waste from sources identified within the Nation

The Nation identified three primary sources of waste to be reduced: Downstream Casino Resort, liquid waste from a meat processing facility, and solid waste from a coffee roastery. The total amount of waste is too low for most commercially-available digesters; therefore, a newly available microdigester could be used.

(2) A large digester with waste sourced regionally

The existing waste streams identified within the Nation are not enough to power a large traditional anaerobic digester (AD). Although the Nation's primary aim is to reduce their own impact, they could do so while also developing a large digester (i.e., approximately 70-150 tons of waste accepted per day) that could serve as a regional hub for organic waste. The Nation is located near several other tribes, each with casinos, and within 100 miles of several major cities in the region: Joplin, Missouri; Springfield, Missouri; and Fayetteville, Arkansas.

(3) Composting

Throughout this study, we focus substantially on the digester options. We have included compost as an option because the Nation initially expressed interest in expanding their current greenhouse composting operation to incorporate other sources of food waste. Ranked as the fifth tier of the EPA's Food Recovery Hierarchy, composting provides a low-cost waste diversion process that would reduce methane emissions from landfill and provide a nutrient-rich fertilizer to improve soil health, increase crop yields and promote water retention.[1] Depending on size and sources of the waste stream, several different composting systems could be considered including aerated static piles, windrows or in-vessel composting. Compost does not produce biogas and thus does not provide the same energy capacity as anaerobic digestion. Although methane emissions are significantly lower than if the waste was landfilled, compost still emits greenhouse gases (GHGs), mostly in the form of CO_2. However, if improperly managed, there is the potential of CH_4 and N_2O emissions, as well as nutrient runoff and water eutrophication.[2]

SELECTION CRITERIA

Working with the Nation, we identified several criteria for evaluating the success of a waste diversion project:

- Reduce the environmental burden of the Nation's waste, including impacts on climate change and landfill capacity
- Build capacity within the Nation
- Produce fertilizer for use in Superfund remediation
- Ensure cost-effectiveness
- Avoid adverse human health impacts and to the extent possible, improve health impacts
- Minimize risks, including permitting times and "not in my backyard" (NIMBY) concerns
- Meet all legal requirements while avoiding complicated legal hurdles

Although not the main focus of the assessment, the Nation is home to one of the worst Superfund sites in the country's history — Tar Creek — and project undertaken should consider if and how it can be of service in the clean up process. The 40 square-mile site — covering half of the Nation's land — was once home to the largest zinc and lead mine in the world. It continues to pose risks to the surrounding communities from degraded water quality, exposure to lead dust, and mine hazards (e.g., sudden land subsidence). The Nation is working with the Environmental Protection Agency to clean up and reclaim the land. They remove about 1 million tons of chat (i.e., remnants of lead- and zinc-laced mine waste) per year with 30 million tons remaining. Since 2015, they have remediated 350 acres of direct chat-filled land, which they plan to use to expand agricultural operations.

Table 1. Evaluation of options based on criteria

	Option 1: Small AD	Option 2: Large AD	Option 3: Compost
GHGs	Less GHG reduction potential than large digester but more than compost	Greatest GHG reduction potential of the three options	GHG reduction potential possible, but compost conditions can be variable and often result in lower GHG reductions than digester options
Diversion from landfill	All of the Nation's organic waste from identified sources diverted	All of the Nation's organic waste from identified sources diverted, plus organic waste sourced from outside the Nation	All of the Nation's organic waste from identified sources diverted
Capacity building within the Nation	Would require ~1 FTE and would allow the Nation to learn the basics of ADs with the opportunity to scale up in the future	Would require ~5 FTE to manage the digester and potentially more for waste hauling. It would help the Nation become experts in ADs, but could be too much given the Nation's interest and capacity now	Would require ~1 FTE but would not give the Nation the opportunity to learn the basics of ADs
Implementation feasibility	Challenging but manageable	Most challenging	Easiest, will likely pursue some form of composting even in the absence of this project
Cost effectiveness	$350,000-$1 million capital costs; operating costs of $31,000 to $50,000 per year	$2 - $5 million capital costs; operating costs range from $34-$55/ton of waste	We did not evaluate compost costs in this assessment, though they are likely much lower than the other options
Health impacts	Health benefits related to air pollution reduction, job creation, and fertilizer production. Minimal health risks.	Health benefits related to air pollution reduction, job creation, and fertilizer production. Minor health risks related to management and increased traffic.	Health benefits related to air pollution reduction, job creation. Minor risks related to leakage.
Legal assessment	No legal barriers to implementation	No major legal barriers, but requires greater contractual commitment and coordination with outside waste sources	No legal barriers to implementation
Permitting risks	Minimal	Manageable, but may require a construction permit	Minimal
NIMBY risks	Likely minimal	Heavy truck traffic from regional waste hauling could cause some concern	Likely minimal though proper management must be used to prevent odor issues

SELECTION PROCESS

After assessing the feasibility of the three different options, we recommended that the Nation move forward with an implementation plan for the small digester and consider how this plan could also inform the design of a new Quapaw casino in Pine Bluff, Arkansas.

There are several companies marketing small ADs that would suit the Nation's existing waste volumes, while reducing costs and logistical hurdles. This option would not produce as much fertilizer as the large AD, nor as many greenhouse gas benefits. On the other hand, the technology gives the Nation some flexibility to start with a small waste stream and take in larger quantities of waste over time.

We reached this conclusion after substantial conversations with several key stakeholders including Craig Kreman (Assistant Environmental Director for the Quapaw Nation), Lucus Setterfield (Director of Food and Beverage for the Downstream Casino Resort), and Stephen Ward (General Counsel to the Quapaw Nation), as well as members of the agricultural department. From these conversations, we learned that the Nation's main priorities, in relation to this project, are (1) to manage food waste from the casino in an environmental and cost-effective manner and (2) to create a fertilizer for use in the Tar Creek remediation. The small anaerobic digester would allow the Nation to meet these priorities while simultaneously building capacity, reducing GHG emissions and providing social and health benefits.

Choosing the large digester option would require the Nation to contract with many outside waste sources, increasing the logistical, financial, and legal challenges. However, it would provide a significant amount of compost, energy, and heat that could be used to offset the Nation's energy costs and costs to clean up a Superfund site on their land. It would also significantly reduce greenhouse gas emissions. Although the potential benefits of a large digester are significant, the associated risks and challenges are likely to outweigh these benefits. The Nation was hesitant to pursue this option given the staffing and expertise demands, and the potential challenges associated with contracting a steady stream of waste from outside sources.

The Nation also requested we consider composting as an option for the casino and coffee roastery wastes. We did not fully evaluate composting in the feasibility study, though concluded that while inexpensive and relatively simple to implement, composting would have minimal carbon benefits.

The stakeholders highlighted the difficulties with completely changing a system and suggested that this plan may best be implemented at the new casino in Pine Bluff, Arkansas. They also strongly emphasized their interest in expanding their compost operations, as there is an extraordinary demand for compost in the Tar Creek clean-up. Based on these two insights, we have concluded that, although this implementation plan is designed for the Downstream Casino Resort, it will serve as a model for implementation in Arkansas. Lastly, our visits to the Nation highlighted the degree of enthusiasm that the Nation has for incorporating sustainable practices into their businesses, operations and lifestyles.

2. TECHNICAL ANALYSIS

Key Findings

- ★ The main identified waste streams within Nation's generate ~3.5 tons / day.
- ★ This amount of waste is too small for a traditional large AD. For in-house waste only, we recommend the Nation use one of the new microdigesters on the market.
- ★ Many sources of waste exist within 100 miles of the Nation that could be used to operate a larger AD.
- ★ Regardless of whether the Nation selects a small or a large AD, we recommend using a two-stage complete mix digester at mesophilic temperatures with an added buffer (cow manure or sodium bicarbonate) and a blending or grinding procedure.
- ★ Either digester size would generate liquid and solid waste that could be used to complement or replace existing soil amendments used in Superfund reclamation.
- ★ Greenhouse gas reduction potential is 348 $MTCO_2e$ for a small AD; 16,531-38,440 $MTCO_2e$ for a large AD; and 219 $MTCO_2e$ for compost.

In the technical analysis, we evaluate the possible inputs, outputs, and design of an anaerobic digester. Figure 1 illustrates possible inputs for a small or a large AD, our design recommendations for the AD, outputs, and possible uses for those outputs. We also surveyed existing ADs for comparison purposes, the results of which are available in Appendix B.

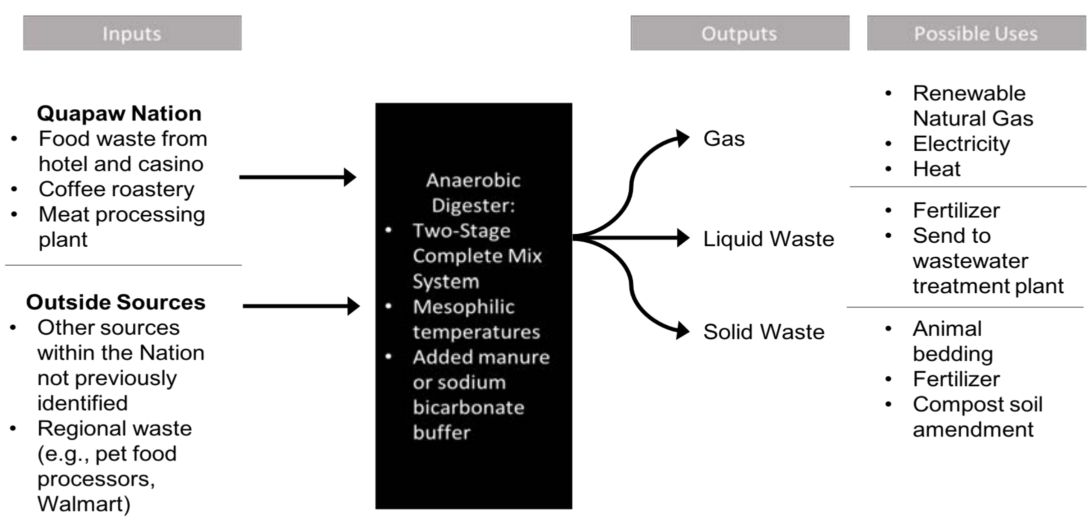

Figure 1. Schematic of options for Quapaw Nation anaerobic digester process.
Source: Authors.

EXISTING WASTE STREAMS WITHIN THE NATION

Within the Nation, waste comes from their casinos, coffee roastery, and meat processing plant. The casinos produce food waste, primarily from the buffet-style restaurants but also from food preparation and standard restaurants. The coffee roastery produces chaff (coffee bean husks which are discarded but are useful substrates for compost[3] or anaerobic digestion).[4,5,6] The meat processing plant is thoroughly cleaned with water that carries away blood, bits of meat, and other organic material from the killing floor and preparation rooms.

Currently, the casino's food waste and coffee chaff is sent to a landfill. Based on information from Republic Services, we assume that the destination landfill is the closest to the Downstream Casino: Oak Grove Landfill in Arcadia, KS. This landfill is approximately 55 miles from Downstream, including a detour through Republic Services' nearest waste transfer station in Galena, KS. Oak Grove has a landfill gas collection system in place, but flares the gas, rather than using it for a beneficial purpose.[7]

The liquid waste from meat processing is sent into two large septic tanks, then passed through a limerock filter and discharged into a local creek.

Before implementation, a detailed waste audit should be performed because the biochemical composition and liquid proportion of waste is important for consistent digester functioning.[8] Waste composition varies widely even within the food industry by factors such as culture-dependent eating habits, climate, handling methods, and restaurant types.[9] Food waste varies significantly by source along all parameters of interest; for example, one summary of the literature reports that food waste ranges from 74–90% moisture content, 80–97% volatile solids to total solids ratio (VS/TS), and 14.7–36.4 carbon to nitrogen ratio.[10] Some wastes are mostly dry, solid matter, while other waste streams are mostly liquid. The type of digester and treatment of the waste (e.g., should it be stirred?) depends on how wet it is. Dry digesters handle waste with more than 15% solids content. Wet digesters are far more common than dry; in a 2016 survey of digesters in the US, the Environmental Protection Agency (EPA) found that 92% were wet digester systems while only 8% were dry.[11] To operate a wet digester, the input waste should be no more than 15% solids.

Table 2. Internal sources of organic waste in the Quapaw Nation.

Source	Composition	Amount *(approx.)*	Methodology	Current Disposal Fate
Coffee Roastery	Chaff (husk of coffee bean removed during roasting)	12 tons/yr	450-500 lbs coffee produced per week;[12] each 50 lb roast produces ~10 gallons of chaff;[13] chaff density is 36 lb/ft3 [14]	Landfilled; methane captured and flared
Downstream Casino Resort	Food waste (pre- and post-consumer)	280 tons/yr	Downstream has 5 restaurants, 3 bars and 2 hotels with 374 rooms.[15] For comparison, the Potawatomi Casino/Hotel has 381 guest rooms and 7 restaurants and a food court. In a 10-week test, that project diverted 3.5 tons/wk of pre-consumer waste.[16] We also know that the Downstream Casino served 1,001,969 people in 2018.[17] Hotels produce on average 1 lb/person/day of food waste and restaurants produce 0.5-1 lb/meal.[18] Given these two estimates, we conservatively estimate 280 tons/yr can be diverted.	Landfilled; methane captured and flared
Meat Processing Plant	Liquid*: Water, meat cuttings, blood	500 tons/yr	10 cattle processed per week and 25 sows processed every 2 weeks.[19] Beef: 50-200 gallons wastewater per animal; hogs: 75-100 gallons wastewater per animal.[20] Thus, 1,250 gallons per week for beef and 2,188 gallons per two weeks for hogs.	On-site septic treatment
Total Waste		792 tons / yr (4,340 lbs / day)		

* Entire head is removed and US Department of Agriculture inspector inspects to ensure there is no brainstem remaining (i.e., ensures no mad cow disease entry into waterways)

REGIONAL WASTE OPPORTUNITIES

From our survey of existing ADs and conversations with experts, we found that a large digester should be sized to take in approximately 70-150 tons of waste/day generate 0.5-2 MW of electricity, respectively. In an EPA survey of US digesters, the average generation was 0.67 MW.[21] Unless an innovative design is used (as discussed below), an digester that takes in less than 70 tons of waste/day is unlikely to be profitable given the relatively large capital costs. On the other side, a large digester runs the risk of odors due to onsite waste storage demands, particularly when the digester needs to be taken offline for routine or unscheduled maintenance.

The Nation could consider building a large digester that draws waste from the broader region (approximately 100-mile radius). We have identified several waste sources that could contribute to such a project. First, there is additional waste within the Nation that may be useful. For example, there are schools and businesses in the town of Quapaw with some pre- and post-consumer waste streams. We estimate the Quapaw schools could provide an additional 10 tons/yr of food waste, though this would not be a consistent input throughout the year.[1]

Using a simple internet search, we compiled a list of businesses that could provide waste inputs to the digester. This list is included in Appendix A. Notably, there are several food distributors and processors — including five pet food processors — within 100 miles of the proposed digester site. We also identified 19 Walmart Supercenters within 100 miles. This is included to demonstrate that a single large contract may be possible in order to aggregate a group of smaller waste streams. Other waste streams such as grocery stores, hospitals, and universities are also in the area, though we did not inventory these.

The Nation also identified other tribes in the area as potential partners. As visible in Figure 2, there are eight tribes in the area surrounding the Quapaw. Each tribe has at least one casino that could potentially supply food waste. The Nation has strong partnerships with these tribes.

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[1] Elementary: 1.13 lbs/student/wk, 321 students; Middle: 0.73 lbs/student/wk, 169 students; High: 0.35 lbs/student/wk, 182 students; 36 wks of school/yr. Sources: https://recyclingworksma.com/food-waste-estimation-guide, https://www.publicschoolreview.com/quapaw-elementary-school-profile, https://www.publicschoolreview.com/quapaw-high-school-profile, https://www.publicschoolreview.com/quapaw-middle-school-profile

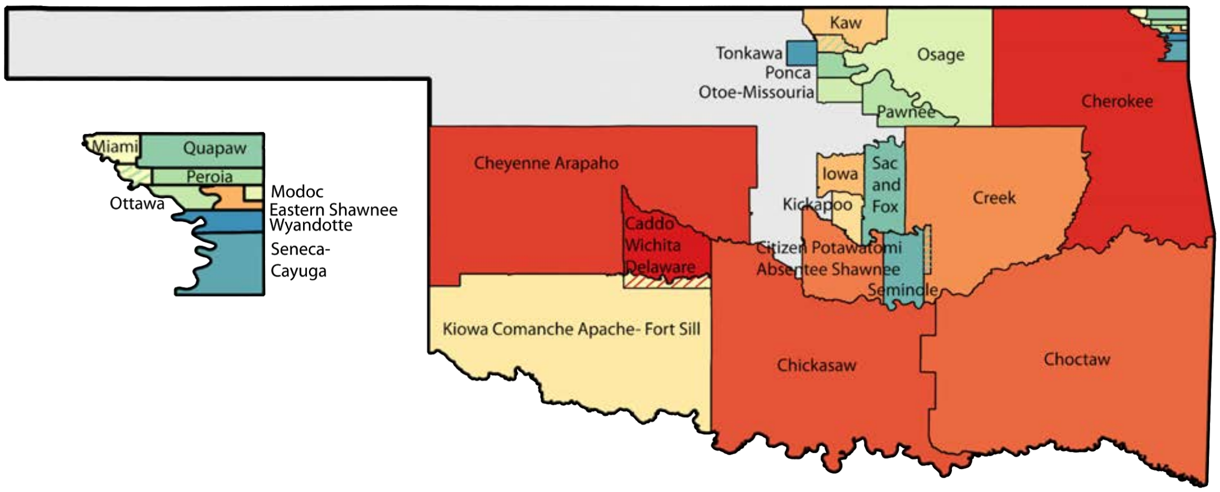

Figure 2. Tribal jurisdictional areas in Oklahoma. *Source: Creative Commons.*

ANAEROBIC DIGESTER TYPE

Regardless of whether the Nation selects a small or a large AD, we recommend using a two-stage complete mix digester at mesophilic temperatures with an added buffer (cow manure or sodium bicarbonate) and a blending or grinding procedure. We further suggest that for in-house waste only, the Nation use one of the new microdigesters on the market.

First, we suggest a complete mix digester. Most ADs are one of four categories: plug flow, complete mix, covered lagoon, and fixed film. Plug flow digesters introduce waste at one end and push it along a long, tubular structure towards the other end, allowing for continuous introduction of waste. They are well-suited to handling relatively high solid content. However, pure plug flow digesters are designed for dairy farms and cannot easily accommodate food waste.[22] Covered lagoon and fixed film digesters can also be ruled out. Fixed film digesters are quick, but they require a very high liquid content and otherwise digestion can be interrupted easily by too-high solids content.[23] Covered lagoons require specific ambient temperature conditions that do not align well with weather in Oklahoma;[24] they are banned in North Carolina for their negative environmental impacts; and they do not produce easily-used digestate.[25] Complete mix digesters are the best option. They are characterized by a large central tank (usually cylindrical) and continuous mixing during digestion. They are more expensive than plug flow and require slightly more liquid waste, but importantly, complete mix can accommodate food waste.[26,27]

Second, we recommend operating at mesophilic temperatures (86°F - 100° F). Different microbial communities thrive under different temperature regimes, each one with advantages and disadvantages for anaerobic digestion.[28] The most common method is "mesophilic," or digestion at temperatures ranging from 35°C-39°C (86°F - 100° F). At hotter temperatures, digesters are "thermophilic:" microbes in these digesters thrive at 50°C-57°C (122°F - 140°F), which can be more difficult to manage but which (i) produce more gas, (ii) generate higher-quality solids, and (iii) requires a smaller tank because the microbes have an increased reaction rate at higher temperatures. In general, mesophilic digesters are easier to manage and run, but they do not kill as many pathogens as thermophilic digestion.[29] The literature on food waste anaerobic digestion focuses almost exclusively on mesophilic digestion,[30,31] and there are several potential problems with thermophilic digestion of food waste. Mono-digestion of food waste at thermophilic conditions causes the accumulation of ammonia (an inhibitor) and volatile fatty acids.[32] Also, in general, at thermophilic temperatures microbial communities are thought to be less diverse and thus less stable[33,34]—i.e., the digestion process is more susceptible to changes or stressors, thus requiring closer monitoring and management.

We recommend adding a buffer in the form of sodium bicarbonate ($NaHCO_3$) and whatever manure is available (more details below). A buffer is required because food waste alone may not be sufficient for a healthy and stable microbial community. In short, food waste alone creates an acidic anaerobic digester;[35] further, food waste alone is comparatively easy to digest for many of the microbes used, which causes a rapid buildup of volatile fatty acids and ammonia inhibition.[36,37] In several studies, researchers found that anaerobic digestion of food waste alone is unstable,[38,39,40] while co-digestion with manure or sewage sludge has synergistic benefits[41,42] and was more stable.[43,44,45] In general, co-digestion provides not only a fuller suite of required nutrients but also improves the kinetics of the necessary microbial reactions.[46] At both mesophilic and thermophilic temperatures, co-digestion increased the microbial diversity in the tanks, which also makes the community more robust to stress.[47] Manure is not readily available in the Nation for two reasons: (i) cows are free-range, and manure is not useful when it is left to dry, but should be scraped or flushed.; (ii) the manure that would be collectable would come only from cows the day before processing, at which time they are penned. However, even a small amount of manure initially injected into the digester could add significant diversity of microfauna.

We recommend that the food waste be pre-treated (blended or ground) prior to digestion. The digester can have problems when waste streams are variable in quality, heavy in grit or inert solids, or contain long, big, stringy material that cannot be easily processed.[48] Variable waste input can cause foaming issues. To combat these potential problems, it is useful to process the waste before it enters the digester. Blending all the solid wastes together can make the input more homogenous (thus reducing the chance that foaming occurs).[49] In one case, food waste from San Francisco was acquired with impurities such as cardboard and metal; it was subjected to a "grinding procedure" before digestion;[50] in general, it is recommended that post-consumer food waste be processed prior to digestion to remove impurities like metal, cardboard, plastic, and similar.[51] Researchers from ICAI School of Engineering in Madrid provide a large and excellent summary of pre-treatment options.[52] Many microdigests include processing equipment that can receive food in cans, bottles, or other packaging.[53]

We recommend two-stage digestion, which is flexible to changes in flow rate of waste and is an economical and efficient way to digest food waste.[54,55] In short, there can be two tanks: one for acidogenesis and hydrolysis, and one for acetogenesis and methanogenesis. The flora of each tank could thus differ. Before injection into the first tank, waste can easily be processed through chopping or grinding. Two-phase digestion also allows for variation in input rate (i.e., can control for days where more or less food waste than normal is injected).

Finally, given the quantity and expected composition of waste in the Nation, we suggest a larger-end "microdigester". In short, the in-Nation waste levels are low. In a survey of US digesters, the EPA reports that the median tons per year of food waste processed in digesters is 13,361 for stand-alone digesters.[56] Likewise, the median gallons per year of liquid waste processed ranged from 2.9 million gallons to 2.2 billion gallons. Clearly, our in-house waste streams are well below these levels (we have ~200 tons of food waste per year and ~1000 tons of available liquid waste per year). There are multiple "microdigester" models available on the market that are an appropriate size for the Nation's existing waste streams.

OUTPUTS OF ANAEROBIC DIGESTION

Biogas

When microbes break down and consume parts of organic waste, they produce biogas. Biogas is useful because it can be processed and used to generate electricity, heat, or fuel. Biogas mainly consists of methane (CH_4; 65-75%)[57] and carbon dioxide (CO_2; 25-30%),[58] but it also contains traces of other gases (e.g., nitrogen, hydrogen, hydrogen sulfide, and water vapor) depending on the input waste materials. Hydrogen sulfide (H_2S) is a harmful element of the biogas produced, because it can damage a generator, so it should be (i) pumped through a column of desulfurizing bacteria or (ii) sent through a scrubber (e.g., iron chloride will chemically remove H_2S).[59] We will discuss this in more detail in the implementation phase. The digester could be configured to produce renewable natural gas for vehicle fuel, which could be used to power vehicles within the Nation.

Liquid Digestate

Digestates—the other product of anaerobic digestion in addition to biogas—are the liquid and solid leftovers of microbes waste processing. Typically, digestate contains carbon and valuable nutrients such as nitrogen, phosphorus, and potassium. It can be processed and used as fertilizer, compost, soil conditioner, or animal bedding; the exact use depends on the inputs to digestion as well as the conditions of digestion (for example, to produce marketable fertilizer, harmful pathogens must be killed in a high-temperature digester or by other means).[60] Liquid digestate can be stored in a large tank onsite and then delivered to remediated land plots to add nutrition back to the soil.

Solid Digestate

Anaerobic digestion produces solid digestate, the exact composition of which varies with the input material. It can be used as animal bedding, compost or plant growth medium, or fertilizer (depending on the nutrient content). Solid digestate also retains water effectively and can be used as a soil conditioner.[61] Solid digestate is commonly treated post-digestion — often by de-watering — to make it lighter and easier to haul.[62] Solids can be de-watered through mechanical procedures such as centrifuges or rotary presses or passive systems such as a drying bed.[63]

Fertilizer Use on Remediated Lands

Remediation of the Superfund site involves removing the top 12-24 inches of the contaminated soil and more as needed until the site is at an acceptable level for contaminants of concern (i.e., lead, zinc, and other heavy metals). Then compost is placed on top of the natural, contaminant-free soil so that the land can eventually be used for an agricultural purpose. It is important to the Nation that we considered how the digester project can be used to aid in the Superfund remediation efforts, if at all.

The Nation currently purchases compost from a local mushroom farm to amend remediated soil. With 30 million tons of chat remaining on their land and a pace of roughly 80 acres per year (1 million tons of removed chat per year), the Nation has a significant need for fertilizer. They have applied compost from a local mushroom farm to over 300 acres (at 20 tons/acre) of tribal land in connection to Superfund land reclamation. This costs them on average $50/ton.[64] Liquid and solid fertilizer are important outputs of the digestion process that could be used to replace or supplement the existing purchased compost. The Nation has indicated they would be open to changing practices if they were producing their own fertilizer. The Nation receives funds from the EPA for the Superfund remediation, which can be used to purchase fertilizer or compost from the digester.

GREENHOUSE GAS REDUCTION BENEFITS

Greenhouse gas reduction benefits come from (a) avoided emissions from diverting wastes from existing landfill or other waste disposal processes (e.g., septic tank) and (b) avoided emissions from switching from grid-based electricity to digester-based electricity.

We used the EPA's Waste Reduction Model (WARM) to estimate the avoided emissions from diverting wastes from existing landfill.[65] This model generates GHG baseline and reduction estimates given information about the amount and type of waste, currently landfill specifications (e.g., landfill gas collection and fate), type of digestion (i.e., wet or dry), and distance to landfill and digester. The WARM model assumes a 25x multiplier for CH_4 relative to CO_2 in terms of global warming potential over 100 years. Electricity estimates used in the model were calculated based on grid emissions factors.

Small AD

The Nation's food waste (i.e., hotel and casino food waste and coffee chaff) is currently transported to a landfill that has landfill gas capture in place with methane flaring (for more details see *Existing*

Waste Streams within the Nation above). The EPA estimates that collection efficiencies at landfills with this technology typically range from 50 to 95%, with an average of 75%.[66] The WARM model estimates that the baseline emissions for the existing food waste is 166.19 $MTCO_2e$ per year. With an AD, these emissions are avoided and emissions from electricity generation, which are biogenic, are considered to have a net zero impact. We assume that the digester is sited next to the Quapaw Nation meat processing plant for purposes of calculating distance waste must be hauled to the AD.

The WARM model does not include a way to calculate the emissions impacts of digesting meat processing wastewater vs. sending it to a septic tank. We estimated the current emissions from the septic tank system are approximately 72.5 $MTCO_2e$/year.[2]

We assume that since the carbon dioxide produced is biogenic that all emissions in the baseline scenario are reduced. We calculated the emissions benefits of switching from the grid to AD-based power given the possible output of a microdigester. As discussed above, an appropriately-sized microdigester has projected capacity of 26 kW for a system that runs 24x7.[3] This can provide an estimated 228 MWh/yr of electricity, offsetting Oklahoma's grid-based energy with an emissions intensity of 1,048.3 lb CO_2e/MWh.[67] We estimate the digester could reduce emissions 109 MT CO_2e/yr from switching electricity sources (Table 3).

Between diverting waste from the landfill and septic system and changing electricity sources, we estimate the Nation could reduce emissions 348 MT CO_2e/yr (Table 3).

We present these values as per year estimates and an estimate of GHG savings over the "lifetime" of the digester. Iowa State University estimates the life of a traditional anaerobic digester plant to be 30 years.[68] Thirty years is the same timeline for the Nation's remediation of the Superfund site. A company that sells an appropriately-sized microdigester suggests that their system has a 20-year design life and we assume a 20-year life for the financial analysis, so use this design life in GHG emissions savings calculations. We estimated the lifetime benefits simply by multiplying the per-year emissions by the lifespan of the system, not accounting for changes in the input waste streams — though the Nation may have estimates of anticipated growth that could better inform this calculation — or changes to landfill gas collection or grid emissions intensity.

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[2] The IPCC estimates that methane emissions from wastewater treated in septic systems are 0.3 kg CH_4/kg BOD (Water Environment Research Foundation, available at http://www.decentralizedwater.org/documents/DEC1R09/DEC1R09.pdf). The USDA estimates for a meat processing plant, the harvesting, packing, and processing will collectively result in 23.5 lb BOD/1000 lb live weight harvested (USDA, available at https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=31475.wba). Typical cattle weight is 1,390 lb (Hamilton, available at https://www.beefmagazine.com/cow-calf/relationship-between-cow-size-production ; typical sow weight is ~280 lbs (USDA, available at https://www.ams.usda.gov/mnreports/lm_hg201.txt). The Nation processes 10 cattle/wk and 25 sows/2 wks. Methane is 25x more potent than CO_2.

[3] According to information about one microdigester on the market, 5,000 lbs of waste per day can generate 3,258 MMBTU/yr, or approximately 30 kW in generation capacity (27.5% efficiency). For the amount of waste we estimate from the Nation (4,340 lbs/day), this can be scaled to 2,828 MMBTU/yr, or approximately 26 kW in generation capacity.

Table 3. Waste sources, current practices, and opportunities for GHG emissions reduction.

Source	Business as usual	GHG Savings	
		Per year (MT CO_2e)	Lifetime (MT CO_2e)*
Casino and coffee roastery	Landfilled, methane capture & flare	**166**	**3,320**
Meat processing	On-site septic treatment	**73**	**1,460**
Electricity source	Oklahoma grid: 46% gas 26% wind 24% coal	**109**	**2,180**
Reduction/year		**348**	**6,960**

We applied the social cost of carbon (SCC) to monetize the emissions reduced from the implementation of the digester. While the SCC attempts to account for much of the environmental, health and economic impacts associated with the reduction of 1 metric ton (MT) of CO_2, it is an imperfect measurement with great variation. For the purposes of this study, we applied the Obama administration's valuation using a 3% discount rate: $42 in damages per MT CO_2. We have also included a sensitivity analysis to account for the range in SCC associated with the chosen discount rate (see Table 4).

We estimated the lifetime of the digester to be 20 years, based on conversations with experts. It should be noted that, this application of SCC assumes that the baseline emissions conditions (i.e., methane flaring at the local landfill and electrical grid composition) remain the same over this lifetime. However, Oklahoma's energy mix has shifted rapidly in the past decade as the wind sector has expanded. Furthermore, as the Quapaw explore the potential of building a solar farm on the Superfund site, the digester may cease to displace GHG emissions.

Table 4. Social Cost of Carbon (in 2007 dollars per MT CO_2e)

GHG Emissions (MT CO_2e)	Obama Administration SCC 5% Discount ($12)	Obama Administration SCC 2.5% Discount ($62)	Obama Administration SCC 3% Discount ($42)	Obama Administration SCC High Impact-95th percentile, 3% discount ($123)
348/year	$4,176	$21,576	$14,616	$42,804
6,960/ 20-year project lifetime	$83,520	$431,520	$292,320	$856,080

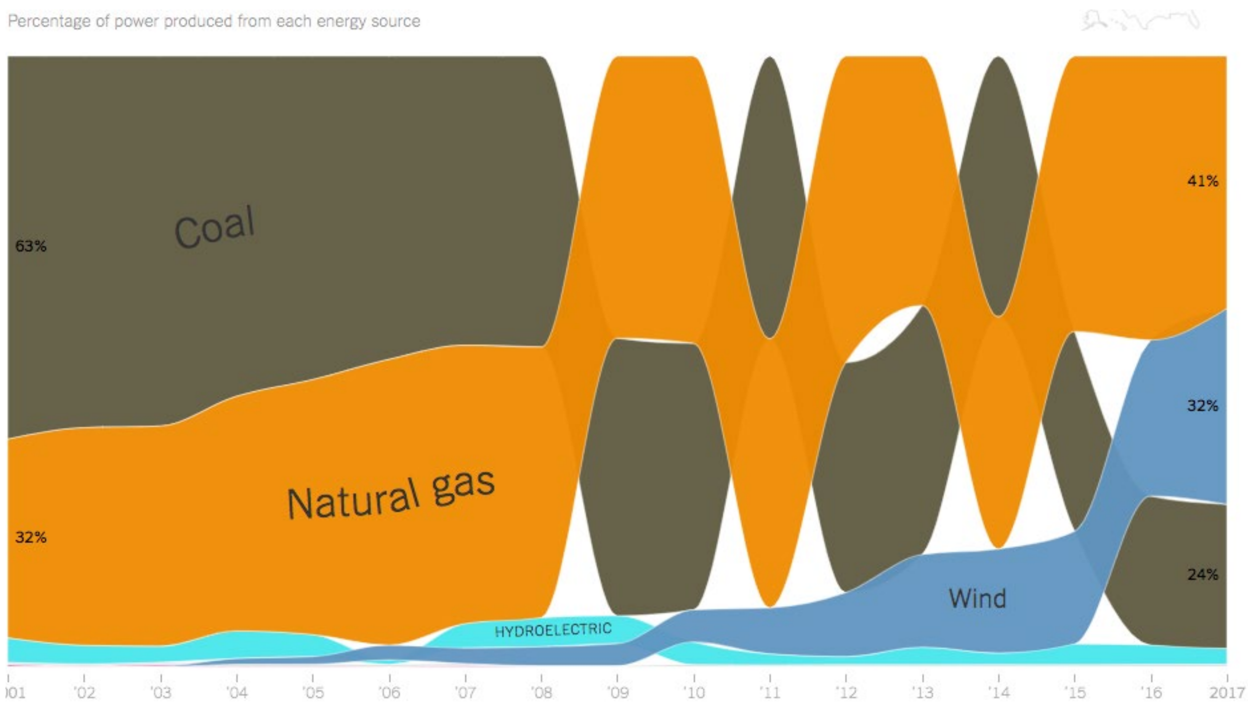

Figure 3. Percentage of power produced from each energy source in Oklahoma from 2001-2017. *Source: New York Times*[69]

Large AD

From our research (see Appendix B, Table 10) and conversations with experts, we estimate that the Nation will need to take in 70-150 tons of waste/day in addition to the identified waste streams from the Nation in order to run a large AD. Meat processing waste is not necessary for operation of the large AD, though may be included. Possible sources of regional waste are identified in Appendix A. We cannot guarantee these wastes will generate sufficient nor consistent enough wastes to maintain an AD.

To generate an emissions estimate, we assume that regional waste currently travels approximately 50 miles to the closest landfill (similar to the Nation's waste) and about 45 miles to reach the Nation (the average distance from the sources identified to the proposed location of the digester). We also assume waste from these sources is currently landfilled, that landfill conditions are the same as Oak Grove Landfill, and that the digester is sited next to the Quapaw Nation meat processing plant. The WARM model estimates the baseline emissions for food waste streams of 70-150 tons/day given this current fate is 14,521-31,116 $MTCO_2e$ per year.

Based on research of other food waste digesters (see Appendix B, Table 10), we estimate that 70-150 tons of waste/day can produce 0.5-2 MW capacity. We assume a large digester will operate 7,448 hours/year. According to the EPA, stand-alone food waste digesters had 29 MW of total installed capacity and collectively produced 216 million kWh/year.[70] Thus, on average, these digesters operated 7,448 hours/year. We then estimate that our digester could generate 3,724-14,897 MWh/year.

Using the eGRID emission factor, the reduction in grid-based energy from the large digester could lead to savings of 1,771-7,085 $MTCO_2e$/year. This method was used for consistency with the methodology for the small AD, but it may be an overestimate; using the WARM model for outside waste estimates electricity benefits to be 1,115-2,389 $MTCO_2e$/year.

Based on our calculations, this option could result in total GHG savings of 16,531-38,440 $MTCO_2e$ per year — approximately the equivalent of taking 3,510-8,161 cars off the road.

Compost

The WARM model provides a quantification option for compost under aerobic conditions. Emissions from composting vary significantly by the waste inputs, biological activity of the pile, and tilling practices.[71] In one study, varying the moisture content of the compost by ~20% led to 1000-fold differences in methane emissions.[72] Under aerobic conditions, methane is not produced, but there can be anaerobic areas of compost piles that do generate methane emissions. For the food waste and coffee chaff sources, composting could result in a GHG savings of 219 $MTCO_2e$ per year — approximately the equivalent of taking 46 cars off the road.

Table 5. Summary of GHG savings (MT CO_2e per year) of waste diversion options analyzed.

		Option 1: Small AD	Option 2: Large AD	Option 3: Compost
GHG savings from waste diversion	Within Nation food waste from Downstream Casino and coffee roastery	166	166	219*
	Meat processing waste	73	73^	N/A
	Outside Nation waste	N/A	14,521-31,116	N/A
GHG savings from electricity source change		109	1,771-7,085	N/A
Total emissions reduction		348	16,531-38,440	219

*Emissions from composting vary significantly by the waste inputs, biological activity of the pile, and tilling practices.

^This waste is not necessary for operation of the large AD.

3. SPATIAL ANALYSIS

Key Findings

- ★ If the Nation implements a non-compost option, they would prefer to site the digester on a 20-acre piece of land that was formerly a sewage lagoon
- ★ This land is adjacent to the meat processing facility and falls under the Tribal Trust land category
- ★ The site is also adjacent to three-phase power and a sizable parking lot

SITE OVERVIEW

The Quapaw Nation currently occupies a 13,000-acre (53 km^2) Quapaw tribal jurisdictional area that crosses three states: Missouri, Kansas, and Oklahoma. The majority of the Nation's operations are in the state of Oklahoma, except for the Nation's Downstream Resort & Casino — their primary revenue source —their greenhouse operations, as well as some portion of their cattle and bison grazing grounds. Due to the complicated nature of Indian land-use, the Nation would prefer to site the digester project on Tribal Trust Land (see Legal section). The preferred site location for the digester is a former sewage lagoon located close to the Quapaw Casino and the Meat Processing Facility. The site is approximately 20-acres in size and is located close to 3-phase power lines (in case the Nation decides to interconnect and digester project with the grid). The Nation has already been evaluating the possibility of locating solar facilities on this site.

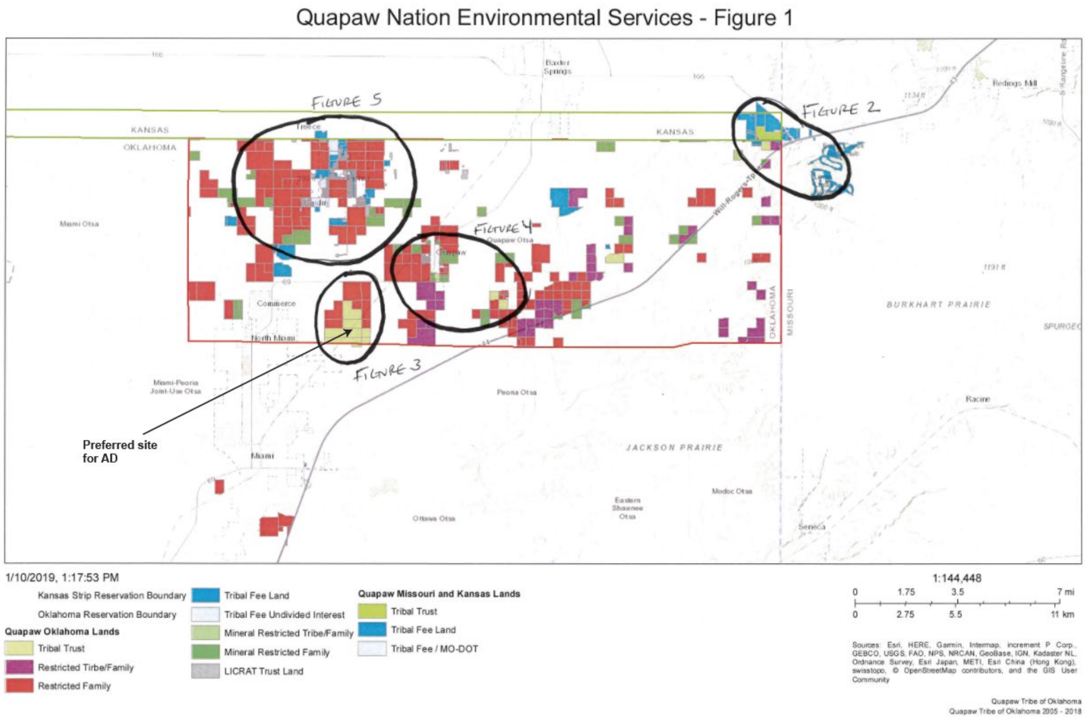

Figure 4. Quapaw Nation Land Allotment Map. *Source: Quapaw Nation.*

Figure 5. Former sewage lagoon and preferred site for AD. *Source: Authors.*

4. FINANCIAL ANALYSIS

Key Findings

- ★ **<u>Waste reduction:</u>** Given the size of the waste inputs analyzed, a small digester or enhanced compost investment could both meet the Nation's waste reduction goals
- ★ **<u>Energy production:</u>** If the Nation would like to prioritize the generation of energy from their waste (something they have expressed keen interest in), at the level of waste inputs analyzed, the small digester option we recommend can potentially offset all the electricity use for the meat processing facility
- ★ **<u>Financial considerations:</u>** The small digester technology, though substantially cheaper than industrial-scale AD's, will still require subsidy/grant support (35-50%) to create a positive NPV and <10 yr payback period.

CAPEX and OPEX vary greatly depending on the size of the AD.[73]

LARGE DIGESTER OPTION

The capital cost for the "large digester option" ranges from $2 - $5 million, while the operating costs range from $34-$55/ton. At minimum these AD's are built to handle 6,000 tons of waste per year. Pursuing this option would require the Quapaw Nation to evaluate the feasibility of trucking waste in from other operations in the surrounding area.

SMALL DIGESTER OPTION

Given the waste input analysis of current Quapaw operations, we are looking at input volume of approximately 800 tons per year, though could leave out the meat processing waste in this scenario. Given this scenario, we believe a microdigester option with a capital investment of $350k to $1M and operating costs of $31,000 to $50,000 per year[74] could make sense for the nation, depending on their access to grants/subsidies to support the project.

QUAPAW ENERGY + WASTE EXPENSE ANALYSIS

The Quapaw Nation owns and operates several different businesses and services for its tribal members and the greater Quapaw and Joplin communities. Given that we are currently looking to pursue implementation of a small digester option, we are specifically interested in the potential for electricity and heating cost savings associated with Quapaw's "behind-the-meter" operations.

These include: Downstream Casino, Quapaw Casino, Quapaw Administration Building, Quapaw Service Authority Building, Quapaw Cattle Company, Quapaw Counselling Services, Quapaw Meat Processing Plant.

Though we do not yet have electricity and heat data for the Casino operations, we know from visiting the Quapaw Nation that the Downstream Casino and the meat processing plant are the Nation's largest energy consumers. Given the electricity, heat and fertilizer requirements for Quapaw operations, we believe the small digester option would deliver 100% of its outputs (i.e., heat, electricity, fertilizer or a combination) directly to Quapaw facilities. Given that the preferred site location for the digester is in close proximity to the meat processing facility and given the energy requirements of that facility, we believe that providing a combination of on-site heat and power to meat processing operations from a small digester would be the recommended approach.

Table 6. FY 2018 Expenses*

Item	Admin	Service Authority	Cattle Company	Counselling	Food Services Authority (Processing Plant)	Totals
Electricity	$180,000	$2,000	$16,000	$3,300	$48,000	$249,300
Lighting	$13,000	0	0	0	0	$13,000
Propane / Natural Gas	$18,000	$3,000	0	0	$12000	$33,000
Trash Service	$43,000	$600	$900	$2,800	$900	$48,200
Mushroom compost for Superfund Reclamation						$87,500
Meat processing waste removal						$900
Total						*$431,900*

**Does not include Downstream or Quapaw Casino*

Additional trash service

In addition to the trash services above, the Quapaw provide household trash removal services for tribal and non-tribal residents outside the Quapaw town boundaries. These dumpsters are located in Picher and have collected over 1,100 tons of waste since May 2015. The associated costs for these dumpsters have exceed $100,000. These are paid for by both grants and tribal dollars.

Compost

As mentioned above, the Nation has applied compost from a local mushroom farm to over 300 acres (at 20 tons/acre) of tribal land in connection to Superfund land reclamation. This costs them on average $50/ton and has cost $300,000 thus far.[75] Digester fertilizer outputs could qualify for subsidies associated with the EPA Superfund as those as those subsidies include costs for re-vegetation.

FINANCIAL MODEL SUMMARY

Below we provide a simplified financial analysis summary pertaining to the investment in a small AD. We used a basic DCF model to calculate a project NPV. We based our "cash-flows" off the electricity cost-savings we expect to achieve at the meat processing facility (based on empire electric rates, we estimate the meat processing facility to use approximately 418,000 kWh annually[76]). Relative to the potential for annual electricity cost-savings, the capital cost for a digester the project will generate a positive 10-year NPV if the Nation is able to cover at minimum 35% of the capital costs with grants or subsidies. If we look at the electricity savings payback period (again, based on the digester providing electricity/heat production to the meat processing plant), we are looking at approximately a 6-8 year payback period, depending on the grant/subsidy amount.

We assume total capital cost of $600,000.

We assume between 35-50% capital costs covered with grants.

Table 5. Summary of financial model.

INPUTS	Coffee	12	tons/yr
	Food waste (pre- and post-consumer)	280	tons/yr
	Liquid*: Water, meat cuttings, blood	500	tons/yr
POTENTIAL OUTPUTS + REVENUE	Options: ENERGY: prime power, heat, hot water, electricity, lighting, or RNG vehicle fuel FERTILIZER: liquid, emulsion, compost, fertilizer, or dried pellets.	13,320 OR 500,000	Ccf/day OR kWh/yr

CAPEX[77]	Microdigester Waste management (trucks etc.)	$300,000-$400,00
OPEX[78]	Digester Waste management ops	$40,000/ Annually $7,384 / Annually

FINANCIAL SUMMARY	10-Year NPV (4%)* 10-Year IRR Simple Payback Period**	$ 7,433.89 - $ 97,433.89 4-10% 6-8 years

***calculated DFC by using electricity savings as "cash-flows"*

***Pay-back period assumes the project offsets all annual electricity consumption at the meat processing plant*

GRANTS

The Quapaw Nation qualifies for a number of grants and subsidies related to both tribal energy endeavors and rural energy capacity building. In addition to this, the Nation receives approximately $15 million per year in EPA subsidies for work related to the reclamation of the Tar Creek Superfund site. We anticipate the Nation will be able to cover a substantial portion of the capital costs with grants and subsidies and is motivated to contribute Tribal funds to the project if it provides the opportunity for employee capacity building and positive social benefits. A list of grants and loans can be found in Appendix C.

5. SOCIAL BENEFIT ANALYSIS

Key Findings

- ★ The Nation is keen to develop projects and create services that lead to greater self-sufficiency and enhanced capacity amongst its tribal members and the community at large
- ★ The Nation is very interested in developing renewable energy on its land, particularly on the reclaimed Tar Creek Superfund Site
- ★ Developing a small digester project could be the catalyst for the creation of two broader sustainability initiatives within the community: waste management and renewable energy development
- ★ In determining the social benefits associated with this project, we recommend a Co-Design social benefit methodology that *"fosters the co-production of knowledge as it relates to energy systems design and implementation by situating the concept of sustainability and sustainable development in the local context of the end user community"*[79]

QUAPAW NATION – SOCIAL RESILIENCE AND SELF-SUFFICIENCY

The history of the Quapaw Nation shares the familiar colonial tale of genocide (population decline), displacement, and relocation at the hands of European explorers and eventually the US Federal Government's territorial expansion. The Quapaw nation have placed great importance on building capacity within the tribe. They are particularly astute in the development of services and businesses that will allow them to "live off their land" and maintain resiliency and self-sufficiency, and they are committed to fostering development that is beneficial to both the environment and the vitality of their tribal members. A testament to this community and cultural commitment is the fact that they have the longest running Pow-Wow west of the Mississippi (over 100 years). The Nation has also shown tremendous resiliency and capacity in how they've responded to and led the Tar Creek superfund reclamation process. One of the potential benefits they see in the reclaiming of this land is the potential for the development of large-scale renewable energy projects – something they are keenly interested in. Given the unique cultural context of the Quapaw nation, we recommend undertaking a new co-design approach to determining and measuring the social benefits associated with the digester project.

Figure 6. Farm-to-Table Casino Operations Advertising. *Source: Downstream Casino.*

CO-DESIGNING SOCIAL BENEFITS

"Just as the dominant discourses of economics, sociology, and political science lack vocabularies to make sense of the untidy, uneven processes through which the production of science and technology becomes entangled with social norms and hierarchies, so too does the engineering discourse lack the language and knowledge production tools alone to make sense of sustainability and sustainable development given their entanglement with often conflicting goals such has the preservation of cultural values via oral communication traditions and the usage modern community technology such as Twitter and smartphones"

Defining the social benefits associated with climate action, and renewable energy project development is contested terrain. Since the concept of sustainability was first introduced in the Brundtland Commission report, sustainability advocates have worked to create frameworks that can pin down the ambiguities embedded in the widely accepted idea of sustainable development, that is:

> "meeting the needs of the present, without compromising the ability of future generations to meet their own needs."

These ambiguities include:

- 'Needs' not being defined
- The process for identifying needs not being defined
- Sustainability indicators or performance metrics for measuring these 'needs' are not defined
- Implicit assumption that decision-makers in the **now** have an idea of what society in the **future** will need

The dynamic nature and unique cultural ecology of different geographic locales further complicates the notion that some grand sustainability framework will work "across the board". In response to the shortcomings of universal sustainability or social impact frameworks, new strides have been made in developing custom social impact frameworks and sustainability metrics.

A recent case study from Berkeley demonstrates a new co-design methodological framework for a unique group of stakeholders to assess the social benefits associated with the design and implementation of a renewable energy system for a North American tribe in California. It seeks to "understand the needs and the social performance metrics that local communities utilize to define sustainability and evaluate technology options for their sustainability and social impact goals." This case study specifically "addresses the shortcomings of our engineering knowledge of partnering with local communities to understand their concept of sustainability, their needs, performance metrics, and indigenous knowledge production methods through a specific design methodology called co-design within the contexts of sustainable community development and the co-production of knowledge."

The co-design methodological framework demonstrated in this case study required numerous rounds of engagement with the community to understand their unique social and cultural ecological realities. It specifically sought to abandon the notion that there are objective social benefits that can be universally applied to every space that develops a renewable energy project. By "fostering the co-production of knowledge as that relates to renewable energy systems design and implementation", the framework creates a way to "identify end user needs and knowledge production methods" that can hopefully optimize the social benefits and measurement techniques required by and for a particular community.

CO-DESIGNING SOCIAL BENEFITS WITH THE QUAPAW NATION

Given the Quapaw Nation's demonstrated commitment to sustainability and their proactive attitude towards everything, we see them the them as an ideal candidate to contribute to the development of the social benefit co-design methodology and ultimately to the creation of new knowledge and understandings about sustainability broadly, and social benefits from renewable energy projects, specifically.

6. HEALTH IMPACT SCREENING RESULTS

Key Findings

- ★ All three project proposals may help improve air quality through waste diversion from the landfill and, to some extent, energy displacement from the grid. This could result in improved respiratory health, including decreased asthma and chronic obstructive pulmonary disease (COPD) incidence.
- ★ Social benefits include job creation, ecotourism marketing and community environmental engagement.
- ★ There are several risks and adverse health effects for the proposed projects, including reduced water and air quality due to leachate. However, with proper management, these impacts can be avoided. The larger digester would see an increase of truck traffic. Proper siting of the digester is integral in reducing harmful impacts.
- ★ It is recommended that community meetings are held to address environmental and health concerns as well as determine best site for project.
- ★ The differences in environmental and health impact between compost and small digester are negligible. While the larger digester may have greater GHG reductions, the localized risks, including occupational health and vehicle pollution, associated are also higher.

Causal Frameworks

For each proposed project, a causal diagram was developed to follow the impacts of each pathway. Accompanying each diagram is the estimated damages saved valuation based on the Social Cost of Carbon (SCC) for each program.[80] The SCC accounts for much of the environmental, health and economic impacts associated with the reduction of 1 ton of CO_2. [81] For the purposes of this feasibility study, the EPA SC-CO2 using a 3% discount rate was applied. For every 1 ton of CO2 emitted, an estimated $42 of damages are associated.[82]

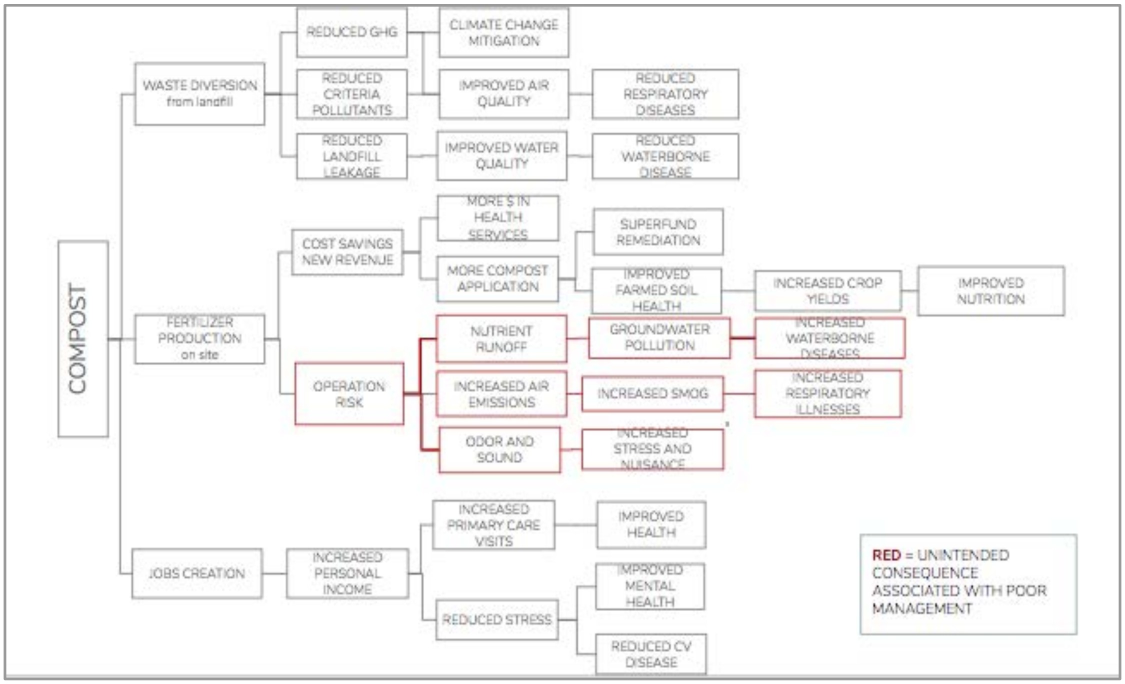

Figure 7. CAUSAL IMPACT OF COMPOST

GHG REDUCED: **219** MT CO_2e per year SOCIAL COST OF CARBON: **$9,198**

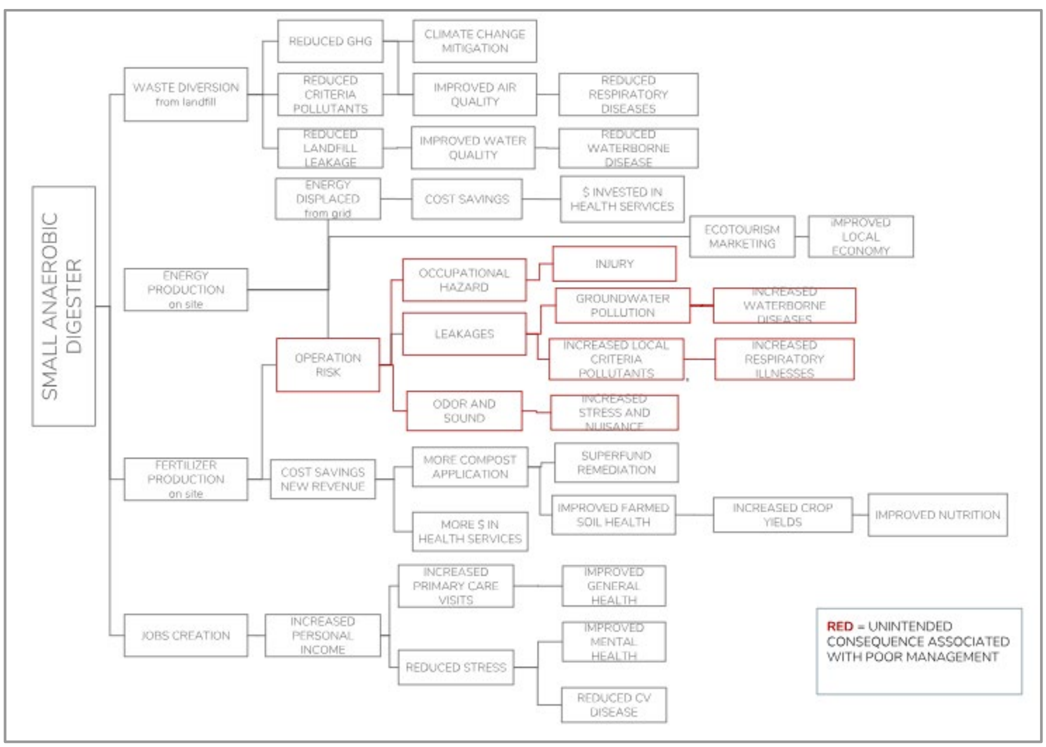

Figure 8. CAUSAL IMPACT OF SMALL ANAEROBIC DIGESTER

GHG REDUCED: 348 MT CO_2e per year SOCIAL COST OF CARBON: **$14,616**

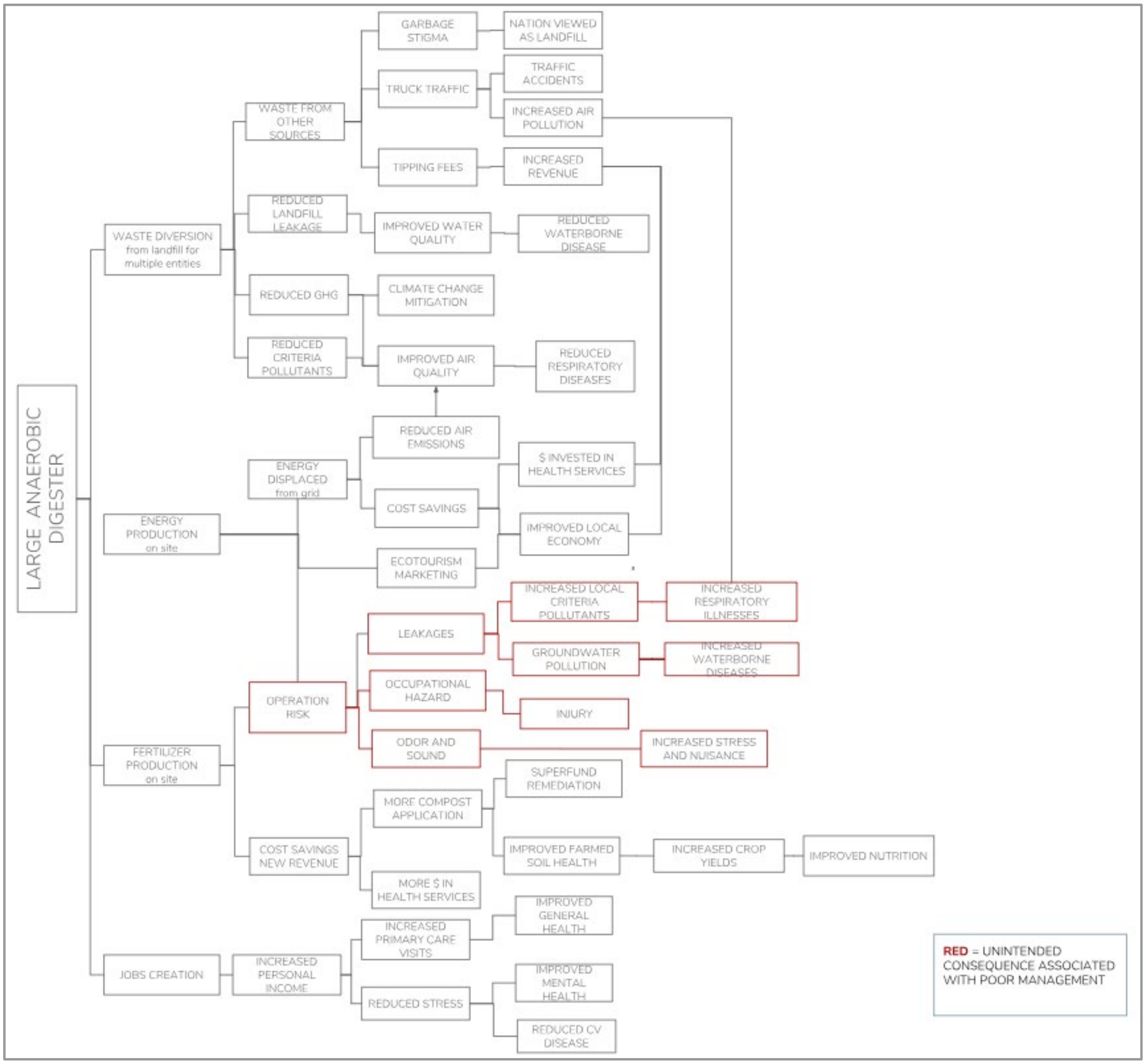

Figure 9. CAUSAL IMPACT OF LARGE ANAEROBIC DIGESTER

GHG REDUCED: **16,531-38,440** MT CO_2e per year

SOCIAL COST OF CARBON: $694,302 -$1,614,480

Table 7. Health impacts of three options considered.

	Option 1: Small AD	Option 2: Large AD	Option 3: Compost
GHGs	Less GHG reduction potential than large digester but more than compost	Greatest GHG reduction potential of the three options	GHG reduction potential possible, but compost conditions can be variable and often result in lower GHG reductions than digester options
Air Quality	Minor improved air quality potential from landfill diversion and grid shift. Potential risk of poor quality through leakage and traffic.	Greater improved air quality potential from landfill diversion and grid shift. Greater risk of poor quality through heavy traffic and leakage.	Minimal air quality impacts
Traffic	Minimal impact-- slight change in traffic patterns	Increased traffic and truck presence. Risk of injury and pollution.	Minimal impact.
Odor and Noise	Minimal impact if monitored properly	Minimal impact if monitored properly	Potential impact of odor, but little to no impact on noise
Water Quality	Minimal impact. Potential benefit from landfill diversion.	Minimal impact. Potential benefit from landfill diversion.	Potential for leachate into water supply causing eutrophication
Occupational Risk	Slight risk of explosion, gas leakage, toxicity and asphyxiation, as well as injury associated with handling equipment.	Increased risk of explosion, gas leakage, toxicity and asphyxiation, as well as injury associated with handling equipment.	Slight risk based on equipment used
Job Creation	Estimated one job created	Estimated one to three jobs created	Estimated one job created
Mental Health	Improved mental health through job and environmental stewardship. Reduced stress	Improved mental health through job and environmental stewardship. Risk through presence of traffic.	Improved mental health through environmental stewardship.
NIMBY risks	Likely minimal	Heavy truck traffic from regional waste hauling could cause some concern	Likely minimal though proper management must be used to prevent odor issues

7. LEGAL ANALYSIS

Key Findings

★ Location: the Nation should build and operate the digester on tribal trust land.

★ Digester: Federal air, water, and solid waste laws do not present any meaningful hurdles to building a digester of any size.

★ Inputs: Contract requirements for waste stream inputs will be more extensive for a large AD, as the Nation will have to work with parties outside the reservation to secure steady waste streams. This option is certainly possible but will be challenging. In contrast, using waste solely from the reservation will not require the Quapaw to contract with outside waste providers.

★ Outputs: Using biogas produced from the digester for heat or electricity directly on the reservation is the best option for the Quapaw from a legal perspective. The Nation is unlikely to produce enough electricity from a small digester to sell electricity back to the utility company. As a result, the Quapaw should use the small digester to produce electricity or heat for the meat process facility or the small casino.

★ Outputs: The Nation could also convert the biogas to renewable natural gas (RNG) if they decide that they would rather offset their natural gas use.

★ Outputs: The Nation can produce and use fertilizer from the digester without obtaining a federal permit.

BRIEF OVERVIEW

State and federal jurisdiction over tribes, particularly in Oklahoma, is elaborate. As a result, this section identifies laws that *could* apply to the Quapaw and points out when jurisdiction is uncertain. To the extent that the Quapaw decide to confine operations to the reservation (for example, if the Quapaw construct a small digester and only use the outputs on the reservation), most jurisdictional complexities will be avoided. But if the Quapaw decide to bring in waste from outside producers or sell outputs from the digester to non-tribal utilities, jurisdiction becomes more complicated. This section seeks to identify and address the maximum legal barriers that could apply.

PERMITTING OF THE DIGESTER

Different Types of Land: Construct the Digester on Tribal Trust Land

In constructing and operating an anaerobic digester (regardless of size), the Quapaw will potentially open itself up to state, federal, and tribal permitting processes. Whether each of these jurisdictions' laws and regulations apply to the digester depends on the type of land on which the Quapaw construct the digester. There are two main categories of modern Indian land ownership: (1) Tribal trust or restricted land; and (2) Fee land (also known as fee simple land).[83] These two categories of land present different jurisdictional requirements.

Tribal trust land is land held in trust by the U.S. government for the use and benefit of the tribe. Tribal trust land is subject to the jurisdiction of federal and tribal laws. In contrast, state jurisdiction is extremely limited on trust land.[84] If the Quapaw build and operate the digester on trust land, they will not be subject to most state regulations and permitting processes. Though the Quapaw could seek state permits on trust land to be safe, they may wish to avoid setting a precedent of applying for state permission that they simply do not need. Restricted Indian land has parallel jurisdictional requirements. Restricted Indian land is held in fee simple by the tribe or an individual member of the tribe, subject to restrictions by the federal government against alienation (i.e., restrictions against selling or giving the property to someone). The Supreme Court has recognized that the federal government holds a strong interest in restricted Indian land and holds the same fiduciary obligations as it does to trust land.[85] As a result, there is no difference for jurisdictional purposes between trust and restricted lands; both are subject to federal and tribal laws and regulations.

In contrast, fee land within a reservation is land in which the Quapaw Nation holds fee simple title (just like any other non-Indian landowner) and which is generally *not* held in trust by the United States.[86] Jurisdiction on fee land is more ambiguous then on trust land. Fee land is subject to more state and local laws than trust land. For example, fee land is subject to federal, *state*, and *local* taxes.[87] As a result, the Nation should avoid operating the digester on fee land, if possible.

Federal: Air and Solid Waste

New Source Review (NSR) is a review program under the Clean Air Act (CAA) that regulates pre-construction of new and modified "major sources" of emissions.[88] While NSR will be something to keep in mind moving forward depending on the size of the digester, a digester is unlikely to trigger NSR permitting[89] and therefore should not be viewed as a hurdle to the project (particularly if the Nation opts for a small digester). Regulations of biomass boilers and steam generating units almost certainly will not apply, as the emission levels they regulate fair surpass anything the digester will generate.[90] The Nation may be subject to federal air regulations limiting emissions from non-road internal combustion engines.[91] For example, 40 C.F.R. 60 Subpart JJJJ sets out requirements for stationary spark ignition internal combustion engines that the Quapaw will likely have to adhere to when operating a digester (although the regulation does not require the owner/operator of the engine to acquire any specific permit).

The Resource Conservation and Recovery Act (RCRA) covers solid wastes, including any "garbage, refuse, [or] sludge from a waste treatment plant . . . including solid, liquid, semisolid, or contained gaseous material resulting from . . . agricultural operations."[92] RCRA does not require permits for digestion of manure on farms.[93] The digester may, however, be considered a waste processing facility subject to RCRA regulations governing non-municipal, nonhazardous waste disposal units assuming it takes in other forms of solid waste, such as food waste.[94] Interestingly, RCRA (unlike other environmental statutes like the Clean Water Act) does not contain a section explaining its application to Indian tribes. The only mention of tribes in the statute is in the definition of "municipality," which includes "an Indian tribe."[95] Still, the Nation is likely governed by RCRA, as the Act does not explicitly exclude application to tribes.

Finally, the Quapaw may need a construction general permit (CGP) under the National Pollutant Discharge Elimination System (NPDES) program (under the Clean Water Act).[96] If the Quapaw opt to operate a small digester, they may be able to get a waiver from the CGP.[97]

State

State laws governing anaerobic digesters almost certainly do not apply to Native American tribes and will not present a significant hurdle to constructing and using a digester. The Oklahoma Department of Environmental Quality has regulations for small (less than 5,000 gallons average daily flow) on-site sewage treatment systems.[98] However, if the Nation builds the digester on Tribal Trust law, these regulations will not apply.

INPUTS: WASTE STREAMS

Contractual Requirements

To construct and utilize a large anaerobic digester, the Nation must obtain a large supply of waste from outside of the reservation. With a large digester, supply risk will be critical, and the Quapaw will have to line up strong contracts with outside waste-providers to minimize this risk and set up a captive source of waste. This is important because a break in the flow of waste could cause problems for a larger digester. At the very least, the Quapaw will have to set up waste contracts with outside providers that match the length and terms of any contracts for the outputs of the digester (i.e., contracts with an electric or natural gas utility, should the Nation decide to sell either one). But to ensure longevity of a larger digester, the Quapaw may want to set up contracts with outside sources that give the Quapaw rights to their waste for at least ten years (twenty would be even better). To make the larger digester feasible, it will be important to be specific in these contracts in identifying the source of waste and term of years. It will also be important to define and obtain full rights to the waste and the gas that comes from it, including environmental attributes.

Finally, the Quapaw should include choice-of-law and choice-of-venue provisions in a contract with outside waste providers. This means that the parties would agree on 1) *where* to litigate any disputes arising from the contract (i.e., what court and what judge/jury); and 2) *what law* will control a contract dispute: tribal or state/local. Ideally, the Quapaw could convince the waste producers to litigate in tribal courts. This may require explaining how the Quapaw court system works and discussing expected damages for breach ahead of time. Additionally, the Quapaw should negotiate to have Quapaw contract law control, if they have relevant contract law. However, Quapaw Code Title 32 "Tribal Contracts" states that the title is "reserved for future legislation." As a result, there do not appear to be current Quapaw rules governing tribal contracts. If the Quapaw do not currently have contract law that would govern a contract dispute with waste providers, the Quapaw could attempt to compromise with outside waste providers by agreeing that state/local law would apply to a contract dispute, but the *venue* for a contract dispute would be a Quapaw tribal court. Although it is unlikely that non-tribal producers will agree to litigate in Quapaw courts, it is worth a try when negotiating these contracts.

In contrast, if the Quapaw decide to build a small digester only using waste from the reservation, they should still create a one-page letter of assignment that lays out who is participating in the project and where the waste is coming from long-term. This will be important if the Quapaw decide to bring in an outside engineering firm or developer, as the letter will demonstrate what waste the Quapaw plan to contribute to the project and assure an outside expert of the feasibility of the project.

Laws/Regulations Governing Transporting Waste Over Reservation Line

If the Quapaw choose to build a large digester and import waste from outside the reservation, they may be subject to Oklahoma's laws governing transporting solid waste.[99] On its face, it is not entirely clear whether Oklahoma's "Management of Solid Waste" regulations would apply to the Quapaw. The regulations apply to "any person who owns, operates, or proposes to own and/or operate any type of solid waste disposal facility identified in OAC 252:515-3-1(a) and (b); (1) any person who generates, collects, transports, processes, and/or disposes of solid waste. . ."[100] Based on the somewhat ambiguous language of the regulation, it is not clear whether transportation of waste would be regulated on its own if the solid waste disposal facility is located on tribal trust land. While state regulations would not touch a facility built entirely on tribal trust land, transportation of solid waste across state lines (and off the reservation) may trigger state regulations. As a result, if the Quapaw choose to bring in waste from producers outside the reservations, they may be subject to Oklahoma's regulations for transporting waste.

OUTPUTS: USE OF GAS, LIQUIDS, AND SOLIDS PRODUCED BY AN AD

Overview

In choosing to utilize an anaerobic digester, the Quapaw must decide how to use the biogas and digestate produced by the digester. While several options may be *feasible* in the sense that the Nation could choose to adopt them, an important step will be deciding which options best meet the Nation's overall goals. This section lays out the different options for the gas and liquids produced by the digester, as well as the legal requirements and hurdles that go along with each.

Biogas Used as an "Off-the-Grid" Resource

Heat

Utilizing biogas from the digester as an off-the-grid resource on the reservation is the simplest option from a legal perspective. Depending on the amount of biogas produced, the Quapaw could combust the biogas and use it for heating on-site.[101] The Quapaw could use the biogas to directly heat homes and buildings, or the Nation's greenhouses. Additionally, if the Quapaw put the digester near the meat processing facility, they could use the biogas to heat the meat processing facility.

Electricity

The Quapaw could also convert the biogas into electricity using different generators and turbines.[102] While the Quapaw have expressed a desire to sell the biogas to utility companies, they will face larger legal hurdles in doing so. At the end of the day, the decision may come down to how much biogas the digester produces. If the Quapaw opt to build a small-scale digester with waste coming solely from the reservation, they likely will not produce enough electricity to sell back to the utility and instead should channel the electricity directly to one of their buildings or facilities. If the Quapaw decide to use electricity directly on the reservation, they will need a simple agreement with their current utility company allowing them to operate a parallel generation unit (i.e., the digester).[103] Their current utility company may already have a standard agreement used to coordinate the operation of parallel generation facilities.

Renewable Natural Gas

To use the biogas produced from the digester as natural gas, the Quapaw will need to upgrade the gas to renewable natural gas (RNG), or biomethane.[104] RNG is "biogas that has been refined to remove carbon dioxide, water vapor, and other trace gases so that it meets natural gas industry standards."[105] Once the biogas is converted to RNG, the RNG can be injected into pipelines and used with conventional natural gas.[106] Interconnection to a natural gas pipeline requires meeting regulations from the Oklahoma Corporation Commission (the public utility), as well as setting up specific contractual agreements for the purchase and sale of natural gas. Interconnecting with a local pipeline can be a lengthy process. As a result, the main hurdle will be beginning this process as soon as possible. On the other hand, the fact that the Quapaw own the interstate natural gas pipeline used to transport gas to the Downstream Casino Resort and store may make interconnection to that pipeline easier.

Regulations Governing Interconnection to a Pipeline

If the Nation selects this option, it will require further legal analysis, as it is a complicated and unclear jurisdictional area. The Oklahoma Corporation Commission publishes rules governing gas utilities. While the Commission stated orally that its rules did not regulate tribal production facilities and transmission serving tribal matters, this seems unlikely if the Quapaw interconnect with a nontribal natural gas utility outside of the reservation. Interconnection with natural gas pipelines is generally a contractual matter, but the Commission gets involved in setting up rules for pipeline safety. For example, pipelines must meet certain strength and construction requirements. If a pipeline is within the Commission's jurisdiction, the Commission will eventually approach the operators to make sure they are meet federal code. Oklahoma has adopted federal pipeline regulations.[107] Federal law likely regulates the sale and transmission of electricity and natural gas in interstate commerce, including onto or through Indian lands.[108] To the extent that the Quapaw already own and use pipelines and would not be constructing new ones, new regulations may not apply. The Pipeline and Hazardous Materials Safety Administration has a tribal assistance program that may be useful in clarifying future questions regarding safety.[109]

Contractual Requirements

If the Quapaw decide to convert biogas from the digester into RNG and use it as natural gas, they will have to complete the Base Contract for the Sale and Purchase of Natural Gas ("NAESB Contract").[110] The North American Energy Standards Board published the NAESB Contract to provide a basic contract that can be "used for both the long-term and short-term purchase and sale of natural gas."[111] The NAESB Contract contains four parts: "i) the Base Contract for Sale and Purchase of Natural Gas (Base Contract), (ii) the General Terms and Conditions to the Base Contract for Sale and Purchase of Natural Gas (General Terms), (iii) one or more transaction confirmations (Confirmation), and (iv) a special provisions addendum (Special Provisions Addendum)."[112] The "transaction confirmation" section for the Quapaw will create terms by which the gas is moved through the pipelines (e.g., how much the Quapaw is allocating into the pipeline from its digester). The Quapaw will also include a biogas addendum as part of the special provisions addendum.

Though the details of the NAESB contract will be worked out down the line, it may be a good idea for the Quapaw to begin communications with the natural gas utility with which they wish to interconnect if they decide they want to produce and sell RNG. The Quapaw obtain natural gas from several utilities (Table 8).

Table 8. Quapaw Nation utility gas services.

Utility Gas Services		
Quapaw Nation governmental offices	Oklahoma Natural Gas	Natural gas utility
Quapaw Food Services Authority (red meat processing facility)	Miami Butane	Propane service
Quapaw Services Authority (construction and remediation authority)	Oklahoma Natural Gas	Natural gas utility
Downstream Casino Resort	Southern Star	Interstate natural gas pipeline—Nation owns the pipeline
Downstream Q Store	Southern Star	Interstate natural gas pipeline—Nation owns the pipeline
Quapaw Coffee (roasting facility)	Hawthorne Propane	Propane service

Source: Courtesy of Stephen Ward.

Because the Quapaw own the pipeline they use to receive natural gas from Southern Star, interconnection with Southern Star would likely be the best option for selling RNG. As a result, if the Quapaw choose to use the biogas from their digester for natural gas, they should consider interconnecting with Southern Star. The Nation will need to reach out to Southern Star to find out about their terms of interconnection and begin negotiating a NAESB contract.

Electric – Interconnection and Sale to Utility

The option of *selling* electricity back to the utility company is an area where the size of the digester and the amount of biogas produced make a difference. As described above, the Quapaw may choose to channel electricity directly into a facility on the reservation without selling excess electricity back to the utility. Should the Nation opt to create a small anaerobic digester, the Nation may not even produce enough electricity to sell electricity back to the utility (or to make such an agreement worthwhile to the utility). If the Quapaw produce electricity for their own use and do not sell it back to the utility, net metering laws will not be relevant.

Conversely, if the Nation chooses to take in waste from outside the reservation and operate a large digester, the Quapaw would have the option of both *producing* electricity for facilities on the reservation and *selling* excess electricity back to the utility. Depending on how much electricity a larger digester produces, the excess electricity in such a situation may go above Oklahoma's capacity limit in its net metering laws. The rates that the Nation ultimately face will affect the feasibility of using biogas from the digester for electricity. Ultimately, harsh net metering laws in Oklahoma may make electric interconnection less worthwhile.

Net Metering Laws

As a general matter, Oklahoma's net metering laws present a major hurdle to selling electricity from the digester to utility companies. Ranked as one of the worst in the country,[113] Oklahoma's system capacity limit for net metering is 100kW or less in size, or 25,000 kWh/year or less (whichever is less).[114] Unless the Quapaw's system capacity is under these numbers, they will not benefit from net metering rate and will be subject to the wholesale rate for electricity produced by the energy market.[115]

Additionally, under the OCC's rules, utilities are not required to purchase monthly excess generation from customer-generators. Instead, "the excess energy shall be provided at no charge to the cooperative/utility."[116]

Arkansas' net metering laws are slightly better than Oklahoma's. Arkansas' system capacity limit is capped at 25kW for residential and 300kW for non-residential (although the Arkansas Public Service Commission may allow a system capacity larger than 300kW on a discretionary basis).[117] Kansas' net metering laws, like Oklahoma's, also limit system capacity to 100kW for non-residential producers.[118]

Ultimately, to figure out whether the Quapaw could take advantage of better net metering laws in neighboring states, the Nation will need to take a closer look at the electric grid with which the Nation wishes to interconnect. Since many electricity grids are not fully contained in one state, they will need to figure out where the Nation would upload the electrons and if there is a direct feed to their sites. Other factors include whether the grids are physically connected and whether the grid owners have a reciprocal relationship.

Contractual Requirements

The Oklahoma Corporation Commission's rules require producers seeking to sell electricity back to utility companies to submit a "written application to the cooperative/utility to purchase the producer's electricity under the applicable purchase rates."[119] The OCC also requires the producer and the utility to create a written purchase agreement.[120] This Power Purchase Agreement (PPA) will address topics such as the length of the agreement, interconnection process, renewable energy attributes, price, and what to do in situations where the purchaser may curtail the producer's energy due to problems with the transmission system (i.e., who will be financially responsible for loss of profit).[121] Again, a PPA is only necessary if the Quapaw choose to sell electricity.

Use of Liquid Waste Produced by the Digester

Federal laws do not generally apply to the use of liquid waste as fertilizer. The Clean Water Act (CWA) does apply to Native American Tribes.[122] Tribes are treated as states for the purposes of section 402 of the Act (the National Pollution Discharge Elimination System (NPDES)).[123] However, the NPDES permitting program does not apply to agricultural activities.[124] The CWA directs the EPA to issue permits for "the discharge of any pollutant."[125] However, the Act defines "discharge of a pollutant" as an "addition" of a pollutant from a "point source."[126] The CWA classifies "agricultural… activities" as "nonpoint sources."[127] As a result, agricultural activities—such as the application of fertilizer to farmland— constitute unregulated discharges under the Act. Additionally, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or the Superfund statute) does not regulate "the normal application of fertilizer."[128]

CONCLUSION

After assessing the feasibility of the three different options, we recommend that the Nation move forward with an implementation plan for the small digester and consider how this plan could inform the design of a new casino in Pine Bluff, Arkansas.

We reached this conclusion after substantial conversations with several key stakeholders including Craig Kreman (Assistant Environmental Director for the Quapaw Nation), Lucus Setterfield (Director of Food and Beverage for the Downstream Casino Resort), and Stephen Ward (General Counsel to the Quapaw Nation), as well as members of the agricultural department. From these conversations, we learned that the Nation's main priorities, in relation to this project, are (1) to manage food waste from the casino in an environmental and cost-effective manner and (2) to create a fertilizer for use in the Tar Creek remediation. The small anaerobic digester would allow the Nation to meet these priorities while simultaneously building capacity, reducing GHG emissions and providing social and health benefits.

The stakeholders highlighted the difficulties with completely changing a system and suggested that this plan may best be implemented at the new casino in Pine Bluff, Arkansas. They also strongly emphasized their interest in expanding their compost operations, as there is an extraordinary demand for compost in the Tar Creek clean-up. Based on these two insights, we have concluded that, although we will design our implementation for the Downstream Casino Resort, it will serve as a model for implementation in Arkansas.

Our visits to Quapaw highlighted the degree of enthusiasm that the Nation has for incorporating sustainable practices into their businesses, operations and lifestyles. In the end, we hope to create a final implementation plan that will be most helpful to the Nation in meeting their environmental and sustainability goals.

Appendix A: Waste Inputs

Table 9. Survey of regional waste streams.

Name	Description of Industry/Waste	Constant (C) or Intermittent (I) Supply^	Driving Distance from Quapaw Meat Processing Plant (miles)	Location
Mars	Pet food manufacturing	C	5	Miami, OK
Cook's Processing	Butcher	C	10.7	Miami, OK
CJ Foods	Pet food manufacturing	C	13.8	Baxter Springs, KS
Columbus Locker	Meat wholesaler	I	19.4	Columbus, KS
Darlington Manufacturing	Commercial bakery, pre-packaged snack foods	C	25.1	Joplin, MO
Protein Solutions	Pet food manufacturing	C	31.1	Joplin, MO
Rembrandt Foods	Egg products manufacturing	C	31.2	Neosho, MO
NutraBlend	Pet food manufacturing	C	32	Neosho, MO
General Mills	Wholesale bakery	C	33.4	Vinita, OK
Heartland Pet Food Manufacturing	Pet food manufacturing	C	35.5	Joplin, MO
Specialty Foods Distribution	Mexican food distributor	I	39.1	Joplin, MO
Ajinomoto Foods	Frozen food packaging	C	41.2	Carthage, MO
Southwest City Meat Processing	Meat processing	C	42	Southwest City, MO
SugarCreek Packing	Meat packing	C	43	Pittsburg, KS
Schreiber Foods	Dairy products distribution & processing	C	45.2	Carthage, MO
Ott Food Products	Dressings, marinades, sauces, dips	C	45.6	Carthage, MO
Kemin Industries	Pet food manufacturing	C	51.7	Sarcoxie, MO

Name	Description of Industry/Waste	Constant (C) or Intermittent (I) Supply^	Driving Distance from Quapaw Meat Processing Plant (miles)	Location
Pepsi	Beverage Distributing	I	54.2	Coffeyville, KS
Hiland Dairy Foods	Dairy products distribution & processing	C	70.2	Erie, KS
Fresh Point	Produce distribution	I	81.8	Lowell, AR
Walmart Supercenter*		I	5.1	Miami, OK
Walmart Supercenter		I	24.5	Joplin, MO
Walmart Supercenter		I	33.2	Neosho, MO
Walmart Supercenter		I	33.2	Grove, OK
Walmart Supercenter		I	39.1	Joplin, MO
Walmart Supercenter		I	40.5	Carthage, MO
Walmart Supercenter		I	40.9	Webb City, MO
Walmart Supercenter		I	43	Pittsburg, KS
Walmart Supercenter		I	44.8	Jay, OK
Walmart Supercenter		I	51.5	Coffeyville, KS
Walmart Supercenter		I	54.9	Parsons, KS
Walmart Supercenter		I	59.3	Pineville, MO
Walmart Supercenter		I	70.1	Bentonville, AR
Walmart Supercenter		I	73.1	Independence, KS
Walmart Supercenter		I	75.8	Rogers, AR
Walmart Supercenter		I	78.1	Bartlesville, OK
Walmart Supercenter		I	79.4	Rogers, AR
Walmart Supercenter		I	85.1	Springdale, AR

***There may be many other big box stores and grocery stores in the region; Walmart is provided as an example. Having so many stores in the area may make it easier to negotiate a partnership with the company.

^ Intermittent and constant waste stream evaluations are guesses based on the entity type.

APPENDIX B: COMPARISON OF EXISTING AD PROJECTS

Table 10. Comparison of inputs, anaerobic digester design, and outputs of several large food waste digesters in the United States.

Digester Project	Waste Type	Waste Volume	AD Design	Electricity Generation	Digestate use
Forest County Potawatomi Community Digester, Milwaukee, WI[129]	Liquid-only food waste and byproducts of food processing industries; also take from their casino	132,000 gal/day capacity, currently operating at 45,000 gal/day	The reactors can operate in both CSTR (continuous stirred tank reactor) and membrane mode; Mesophilic	2 MW (max)	Solids land applied; liquids to local WWTP
Stop & Shop Freetown, MA[130]	Grocery store waste	70-100 tons/day	Complete mix	1.1 MW	Solids become compost
San Jose, CA[131]	Commercial food waste	90,000 tons/yr (~250 tons/day)	Dry fermentation system; Thermophilic	1.6 MW	Produces feedstock for composting
Michigan State Univ. – South Campus Anaerobic Digester[132]	- Manure 7,000 ton/yr - Food processing waste 4,000 ton/yr - Fats, oils, grease 4,000 ton/yr - Cafeteria food waste 500 ton/yr	10,000 ton/yr	Complete mix; Mesophilic	0.34 MW	Compost & liquid fertilizer for campus and nearby agricultural land
Vermont Tech Community Anaerobic Digester[133]	Manure, energy crops, food-processing residuals, and (pending permit) pre- and post-consumer food residuals	Up to 15,840 gallons	Two-stage complete mix; Mesophilic	0.32 MW	Solids used for bedding, creating compost, and spreading directly on fields; liquid is either spread on fields or moved to a holding pond at the campus farm
University of Wisconsin[134]	- 53% food waste - 23% yard waste - 24% farm bedding	10,000 tons/year	Dry* fermentation system, batch; Mesophilic	0.37 MW	Liquid waste land applied; Solids composted or sold

	Input moisture content must be less than 75%				

* Yard waste must be digested in a dry environment.

Case Study: Forest County Potawatomi Community Digester, Milwaukee, WI[135]

The Forest County Potawatomi Community Digester is a food waste digester project located on tribal lands and managed by a tribal nation. Notably, it is located in Milwaukee, WI, in an urbanized area.

The digester takes in food waste from the Potawatomi casino located next door and liquid food waste from a variety of regional sources, currently ~45,000 gallons/day with ~3.5 tons/week of pre-consumer waste from the casino.[136] Ninety percent of the pre-consumer food waste comes to the digester via an innovative food waste recycling system called Grind2Energy, made by InSinkErator. The system grinds the casino's food waste and pumps it into an on-site, 2,000-gallon storage tank.[137]

The Potawatomi own land outside of Milwaukee but chose to site the digester in the urban area because of the proximity to regional waste streams. However, the urban setting presented some challenges when designing the AD, since the community felt strongly about reducing all odors and other impacts on the community. By only taking liquid waste, they avoid dropping any waste on the truck bay floor. They have also installed odor-stripping and -minimizing technologies.

When waste comes to the plant, it is stored in several equalization tanks and held so engineers can mix appropriate wastes together and make use of the specific types of materials at the right time to avoid harming the microbes in the digester. The digester is a complete mix digester run at mesophilic temperatures. The plant was seeded with activated sludge from a local wastewater treatment plant, but once running requires no additional buffer inputs. One time, an input killed the microbial community and crashed the digester.

The biogas is burned in a turbine and sold to the utility as part of a 15-year power purchase agreement (PPA) and can provide a maximum of 2 MW of electricity. When the PPA expires, all electricity will be used to power the casino. Heat is currently sent to the casino. The liquid and solid digestates have been problematic for the project. The liquid effluent is sent to the Milwaukee Metropolitan Sewerage District's wastewater treatment plant, which dries sewage sludge and processes it into a fertilizer.[138] However, the digester project has violated its discharge permits several times.[139] The local compost facility will not accept the plant's solid waste because the plant uses a polymer (i.e., plastic) in the flocculant used to separate liquid and solid wastes; the digester operators are in search of a better disposal process for the solid waste and hopefully one with a beneficial use for the soil amendment. This is less likely to be a problem for the Quapaw Nation project because the rural area may allow the Nation to store digestate until it can be used.

The Potawatomi digester cost approximately $20 million. This was funded via several sources, including a grant from the Department of Energy that covered 30% of the project costs. Unfortunately, this grant mechanism was part of the American Recovery and Reinvestment Tax Act and has expired. The upfront cost is also significantly higher than many comparable projects; this is due in part to the unique siting of the facility, odor control systems, and equalization technologies. Ongoing, the digester is run by five full-time staff.

Table 11. Food Waste Anaerobic Digestion Costs and Capacity. *Source: Moriarty, K. (2013). Feasibility study of anaerobic digestion of food waste in St. Bernard, Louisiana. Natl. Renew. Energy Lab., no.*

Anaerobic Digester Owner	Capacity	Capital Costs	Cost per Ton	Operational Costs	Tipping Fee	Energy Output
	tons/year	Million $	$/ton	$ per ton	$ per ton	
East Bay Municipal Utility District[a1]	7,500-15,000	$2-5	$266-333	$40-55	$40	220 kWh/ton
City of Toronto[1]						
Existing	40,000	$18	$450	$90		107m³/tonne biogas
Planned	27,500	$23	$836			unknown
Planned	55,000	$34	$618			unknown
University of Wisconsin (pilot)[2]	6,000	$2.3	$383			400 kW
Cedar Grove Composting, WA[b1]	280,000	$87	$309			8 MW
Humboldt County, CA[1]	10,000	$6	$600	$34	$60	2,400 MWh/yr
w2E[3]	48,000	$23	$479		$35	3.2MW
a-used capacity in an existing digester; expenditures were for pre-processing and energy generation equipment						
b-facility already has pre-processing equipment for composting operation						
1-"Update on Anaerobic Digester Projects Using Food Wastes in North America." Institute for Local Self Reliance. City of Atlanta. October 2010.						
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APPENDIX C: SUMMARY OF GRANT AND LOANS AVAILABLE

Table 13. Summary of grant and loans available.

Type	Name	Details
Loan Guarantee / Grant	Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants[140]	Guaranteed Loan Terms - $5,000 minimum loan amount - $25 million maximum loan amount Renewable Energy System Grants: - $2,500 minimum - $500,000 maximum
Grant	Rural Energy for America Program Energy Audit & Renewable Energy Development Assistance Grants[141]	$100,000 MAX for eligible activities
Grant	US Bureau of Indian Affairs (BIA) - Energy and Mineral Development Program (EMDP)[142]	Projects that assess, evaluate, or otherwise promote the productive use or development of energy and mineral resources on Indian lands. Grant awards are discretionary, and subject to the availability of funds as appropriated by Congress on a year-to-year basis.
Loan Guarantee	DOE - Tribal Energy Loan Guarantee Program[143]	$2 billion for tribal economic opportunities
Loan / Grant	Community Facilities Direct Loan & Grant Program[144]	
Grant	Indian Land Tenure Foundation[145]	
Loan Guarantee	US BIA - Indian Energy + Economic Development[146]	
Grant	US BIA - Tribal Energy Development Capacity[147]	$10,000-$1M
Grant	Clean Diesel Tribal Grant[148]	$800,000
Energy Management Capacity Grants (Indirect)	● Clean Diesel Tribal Grant[149] (potential option for replacing Tar Creek reclamation "fleets" with biogas from AD) ● Tribal Energy Development Capacity[150] ● Tribal Solar Accelerator Fund[151] ● Rural Business Development Grant Program[152] ● US EPA - Energy MGMT Analysis[153] ● US EPA - Energy Star Training[154] ● Biorefinery[155] (commercial scale) NREL - Energy Decision Mgmt Support[156]	

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[94] 40 C.F.R. Subpart B - Disposal Standards for the Receipt of Very Small Quantity Generator (VSQG) Wastes at Non-Municipal Non-Hazardous Waste Disposal Units.
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[96] *See generally* "EPA's 2017 Construction General Permit (CGP) and Related Documents," *available at* https://www.epa.gov/npdes/epas-2017-construction-general-permit-cgp-and-related-documents.
[97] *See* "Appendix C – Small Construction Waivers and Instructions," *available at* https://www.epa.gov/sites/production/files/2017-02/documents/2017_cgp_final_appendix_c_-_waivers_508.pdf.
[98] *See* Title 252, Ch. 641, *available at* http://www.deq.state.ok.us/rules/641.pdf.
[99]Title 252. Department of Environmental Quality Chapter 515. Management of Solid Waste. Available at http://deq.state.ok.us/rules/515.pdf.
[100] *Id.*

[101] *See Clean Energy Development for Thurston County: Phase 1: South County Community Digester Project Opportunities* (May, 2016) at 15, *available at* http://www.energy.wsu.edu/Documents/Clean%20Energy_South%20Thurston%20Digesters_Phase%201%20Final%20Report_May2016.pdf.
[102] *See id.*
[103] Oklahoma Administrative Code, 165:35-29-2. Parallel operation of generation facilities.
[104] *Fact Sheet - Biogas: Converting Waste to Energy*, Environmental Energy and Study Institute (Oct. 3, 2017), https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy#3.
[105] *Id.*
[106] *Id.*
[107] 49 C.F.R. Parts 191, 192, 195. The Commission's pipeline safety regulations are in the Oklahoma administrative code OAC 165: 20. They have been adopted and approved by the State of Oklahoma.
[108] Martin v. Kirkwood, *Federal and State Regulation of Tribal Utilities*, Natural Resources & Environment, Vol. 7, No. 4, Developing Resources on American Indian Lands (Spring 1993) at 28. *Available at* https://www.jstor.org/stable/40923249.
[109] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/subdoc/3731/phmsa-tribal-assistance-protocol-march-2018.pdf
[110] NAESB, Base Contract for the Sale and Purchase of Natural Gas Standard 6.3.1. (Apr. 19, 2002), available at https://naesb.org//pdf/cs012102w2.pdf.
[111] Press Release, NAESB, Contract for Purchase and Sale of Natural Gas, with Canadian Addendum, Approved by NAESB Wholesale Gas Quadrant (April 23, 2002), available at http://www.naesb.org/pdf/042302pr.pdf.
[112] Karen Goepfert, *For the Long Haul: The Suitability of the Base Contract for the Sale and Purchase of Natural Gas for Long-Term Transactions*, 27 Energy L.J. 583, 584–85 (2006).
[113] *See* http://freeingthegrid.org/#state-grades/oklahoma.
[114] Net Metering; Program Overview, DSIRE (updated Nov. 30, 2018), http://programs.dsireusa.org/system/program/detail/286. *See also OCC Standard Terms of Purchases*.
[115] *See* Standard purchase schedules for power producers of 100kW or less from Empire Electric, *available at* https://www.empiredistrict.com/CustomerService/Rates/Electric/OK. We will need to compare these numbers to the wholesale rate.
Rates from Grand River Damn Authority: *compare* Wholesale Tribal Utility (see http://www.grda.com/wp-content/uploads/2010/12/WTU-2-effective-2019.04.01.pdf) *with* http://www.grda.com/electric/customer-service/retail-sales/. *See also Wholesale v. Retail Electricity Costs*, ISO New England, *available at* https://www.iso-ne.com/about/what-we-do/in-depth/wholesale-vs-retail-electricity-costs.
[116] *OCC Standard Terms of Purchases*, 165:40-9-3. Purchase rate.
[117] http://programs.dsireusa.org/system/program/detail/536.
[118] http://programs.dsireusa.org/system/program/detail/3403.
[119] 165:40-3-1. Application for purchase agreement. Title 165. Corporation Commission, Chapter 40. Standard Terms of Purchases from Purchasers of 100 KW or Less [hereinafter, "*OCC Standard Terms of Purchases*"] *Available at* http://www.occeweb.com/rules/CH%2040%20Effective%209-12-14%20searchable.pdf.
[120] *Id.*
[121] *See* Daniel A. Yarano, *The Basics of a Power Purchase Agreement*, Biomass Magazine. *Available at* http://biomassmagazine.com/articles/2119/the-basics-of-a-power-purchase-agreement.
[122] 33 U.S.C.A. § 1377(a) *Indian Tribes - Policy* (" Indian tribes shall be treated as States for purposes of such section 1251(g) of this title").
[123] 33 U.S.C. § 1377(e) *Indian Tribes - Treatment as States.*
[124] 33 U.S.C. § 1342 (l) Limitation on permit requirement—(1)Agricultural return flow ("The Administrator shall not require a permit under this section for discharges composed entirely of return flows from irrigated agriculture, nor shall the Administrator directly or indirectly, require any State to require such a permit"). Indeed, the definition of "point sources" in the Clean Air Act does not include agricultural stormwater discharges and return flows from irrigated agriculture. Instead, "agricultural…activities" constitute "nonpoint

sources" under the CWA. 33 U.S.C. § 1314(f).
[125] 33 U.S.C. § 1342(a)(1)
[126] Id. § 1362(12).
[127] 33 U.S.C. § 1314(f). *See also* "Basic Information About Nonpoint Source (NPS) Pollution," Environmental Protection Agency, *available at* https://www.epa.gov/nps/basic-information-about-nonpoint-source-nps-pollution.
[128] 42 U.S.C. § 9601(22).
[129] Charlie Opferman, Personal communication.
[130] https://americanbiogascouncil.org/resources/biogas-projects/; https://www.ecori.org/composting/2018/5/14/donate-recycle-and-digester-drive-stop-shop-toward-zero-waste; https://www.wbur.org/bostonomix/2017/04/21/anaerobic-digester-food-waste-energy;
[131] https://www.zankerrecycling.com/zwedc/
[132] https://www.americanbiogascouncil.org/projectProfiles/eastLansingMI.pdf
[133] *Vermont Tech Community Anaerobic Digester*. (2019). *Vermont Tech Community Anaerobic Digester*. Retrieved 9 May 2019, from http://digester.vtc.edu/
[134] https://www.americanbiogascouncil.org/pdf/ABC-Clarkson-Digester.pdf; https://uwosh.edu/biogas/urban-dry-systems-bd1/; https://www.tpomag.com/editorial/2018/05/a-wisconsin-university-explores-the-frontiers-of-efficient-anaerobic-digestion
[135] Unless otherwise noted, all information was provided by Charlie Opferman, VP of Operations at FCPC Renewable Generation, LLC, during a call on March 13, 2019.
[136] Emerson, D. (2014). *From Casino Kitchens To On-Site Digester - BioCycle*. Retrieved 9 May 2019, from https://www.biocycle.net/2014/05/15/from-casino-kitchens-to-on-site-digester/
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[141] *Rural Energy for America Program Energy Audit & Renewable Energy Development Assistance Grants | USDA Rural Development*. (2019). *Rd.usda.gov*. Retrieved 9 May 2019, from https://www.rd.usda.gov/programs-services/rural-energy-america-program-energy-audit-renewable-energy-development-assistance
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[146] *Loan Guaranty, Insurance, and Interest Subsidy Program | Indian Affairs*. (2019). *Bia.gov*. Retrieved 9 May 2019, from https://www.bia.gov/as-ia/ieed/loan-guaranty-insurance-and-interest-subsidy-program

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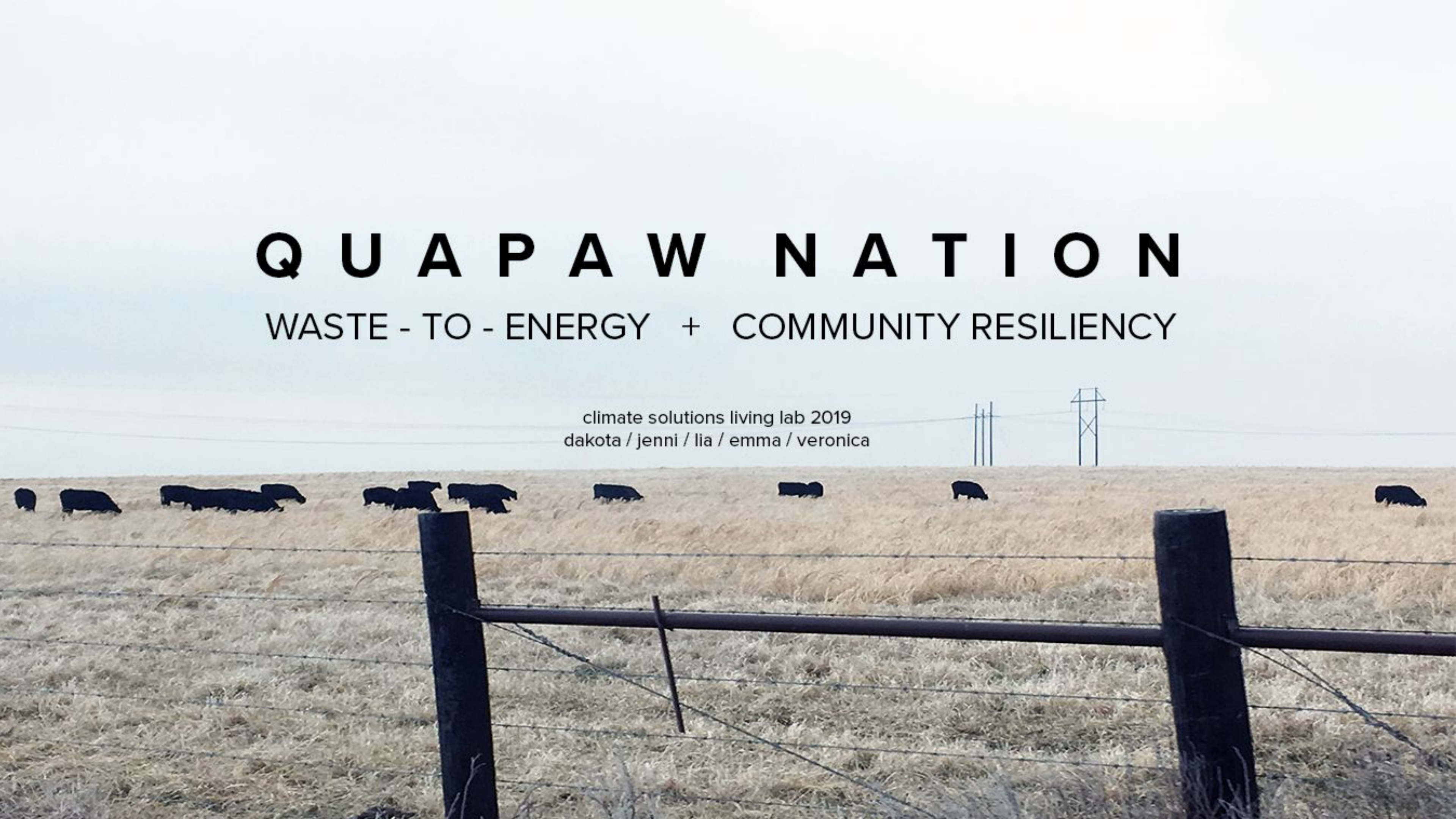
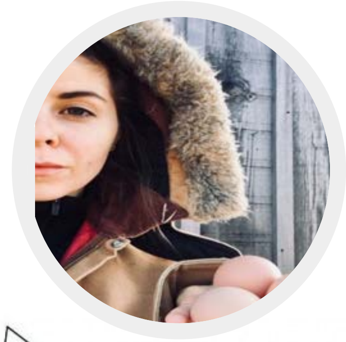

QUAPAW NATION
WASTE - TO - ENERGY + COMMUNITY RESILIENCY
climate solutions living lab 2019
dakota / jenni / lia / emma / veronica

Jenni Matchett



Harvard University
Graduate School of Design

Dakota McCoy

HARVARD UNIVERSITY
The GRADUATE SCHOOL *of* ARTS AND SCIENCES

Lia Cattaneo

HARVARD Kennedy School
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Emma Pollack

HARVARD T.H. CHAN | SCHOOL OF PUBLIC HEALTH

Veronica Saltzman

HARVARD
LAW SCHOOL

we acknowledge that the LAND on which the school sits is the TRADITIONAL TERRITORY of the Wampanoag, Nipmuc and Massachusett people.

quapaw

quapaw

tar creek superfund site

project goals

_ ENVIRONMENTAL STEWARDSHIP

_ COMMUNITY CAPACITY

_ FOOD WASTE

tangible, replicable, scalable

_ GHG REDUCTIONS

_ WASTE-TO-ENERGY SOLUTIONS

_ HEALTH & SOCIAL BENEFITS

business as usual

CO_2

CARBON DIOXIDE

CH_4

METHANE

landfill

ORGANIC WASTE DECOMPOSES ANAEROBICALLY

if food waste were a country...

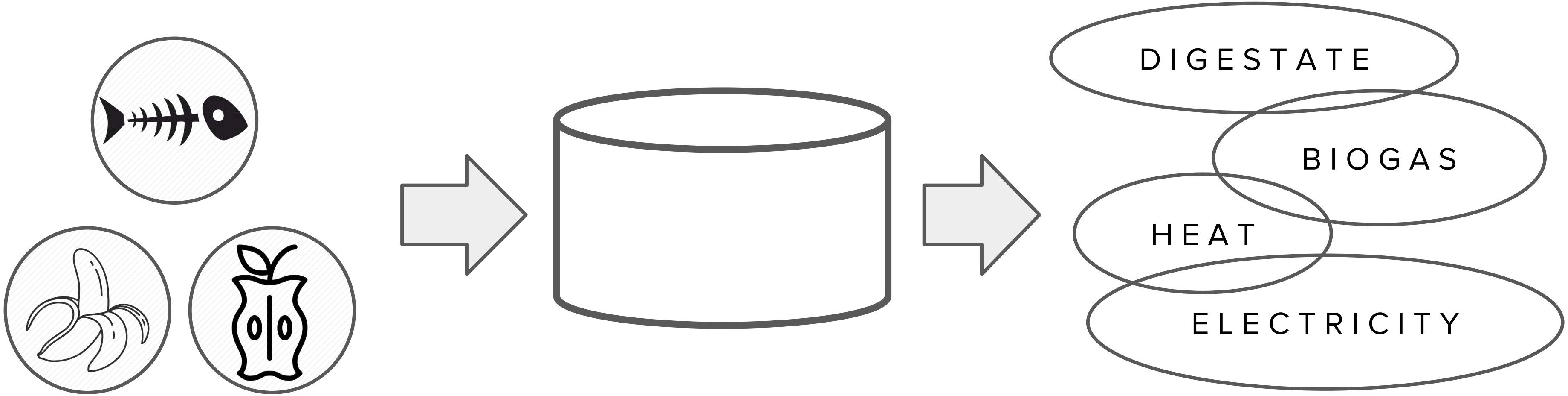
3rd

GREATEST

GHG EMITTER

40 % food wasted in US

anaerobic digestion



ORGANIC WASTE

ANAEROBIC DIGESTER:
MICROBES + NO OXYGEN

OUTPUTS

quapaw sustainable ventures


coffee roastery


meat processing

farm-to-table greenhouse

downstream casino


micro brewery

?

digester inputs

CHALLENGE:
"TOO LITTLE" WASTE
+ NO USEFUL MANURE

WASTE SOURCE	AMOUNT
COFFEE ROASTERY: coffee bean husks	12 tons/yr
DOWNSTREAM CASINO: food waste	280 tons/year
MEAT PROCESSING: water, meat cuttings, blood	500 tons/yr
TOTAL WASTE	**792 tons/yr** (4,340 lbs/day)

selection process

OPTION 1: MICRO-DIGESTER
200-1,000 tons/year

OPTION 2: LARGE ANAEROBIC DIGESTER
10,000-200,000 tons/year

OPTION 3: COMPOST

selection process

OPTION 1: MICRO-DIGESTER
200-1,000 tons/year

OPTION 2: LARGE ANAEROBIC DIGESTER
10,000-200,000 tons/year

OPTION 3: COMPOST

class priorities + nation's goals

micro-digester

OPTION 1: MICRO-DIGESTER

200-1,000 tons/year

Fertilizer

177,138 gal/yr

Revenue stream!

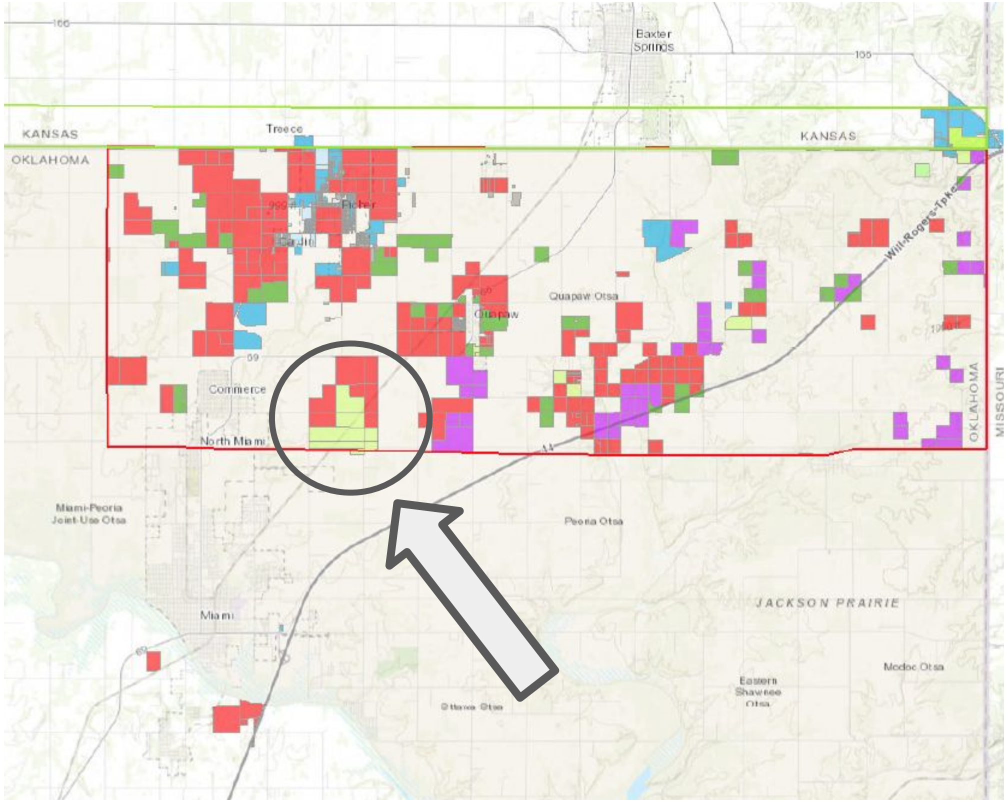
$0.75 - $3.50 per gallon

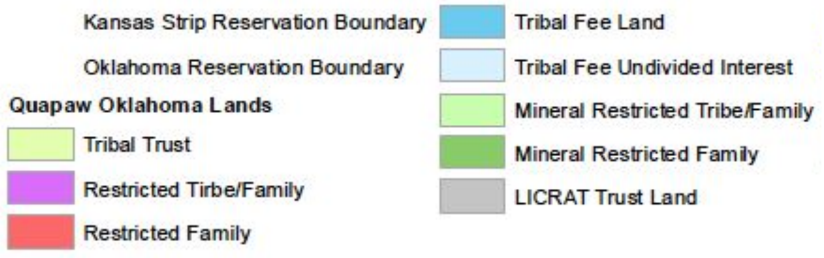
Electricity

228,000 kWh/yr

~50% of meat processing facility power needs!

legal framework





1. TRIBAL TRUST
2. FEE SIMPLE

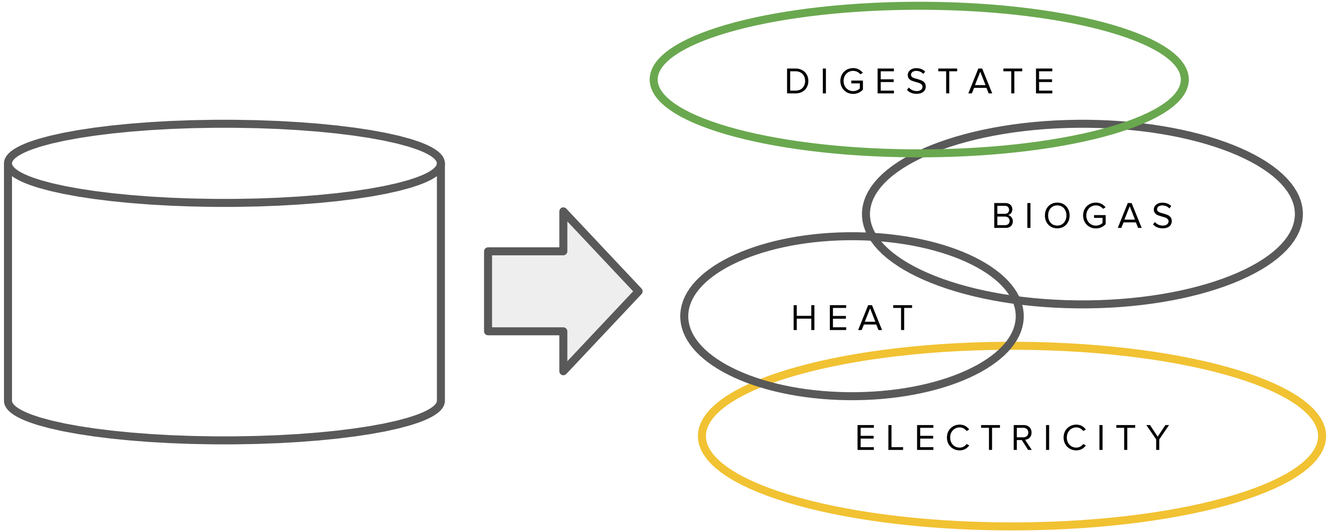
federal regulations

FEDERAL

AIR
WATER
SOLID WASTE

Tar Creek mine collapse

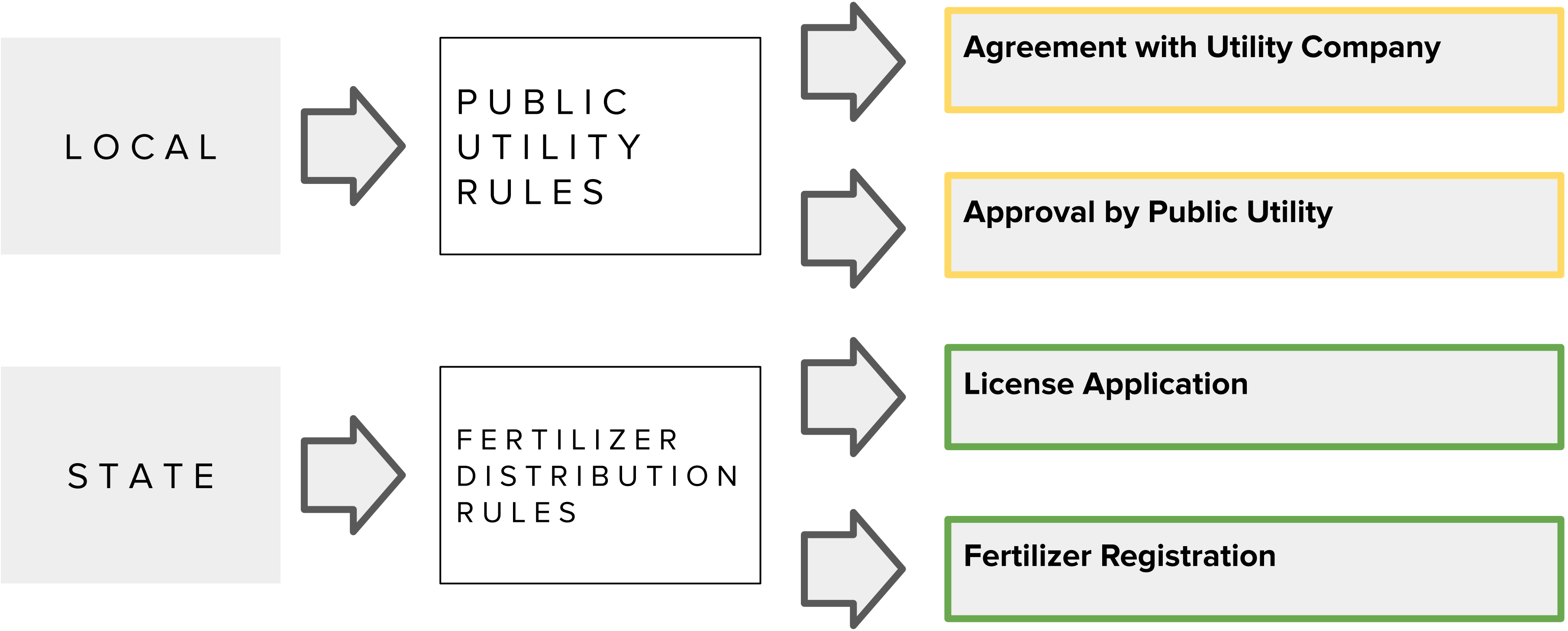
outputs



ANAEROBIC DIGESTER

OUTPUTS

outputs: state/local regulations



financial analysis

Costs

CAPEX
OPEX

Revenues / Cost Savings

Biofuel
Heat/Power
Fertilizer / digestate
Avoided social cost of carbon

Financing Options

Debt
Equity
Carbon offset investors
Grants/subsidies

quapaw assumptions

Costs

Micro AD
Truck
O+M

Revenues / Cost Savings

Avoided electricity cost
Avoided waste removal costs
Liquid fertilizer revenue

Financing Options

Equity
Grants/subsidies

financial summary

COSTS	TOTAL
CAPEX	$800,000
OPEX	$41,000 / year
REVENUES	
AVOIDED COSTS	$37,140 / year
FERTILIZER SALES	$183,781 / year
20 YEAR NPV (8% discount rate)	$950k

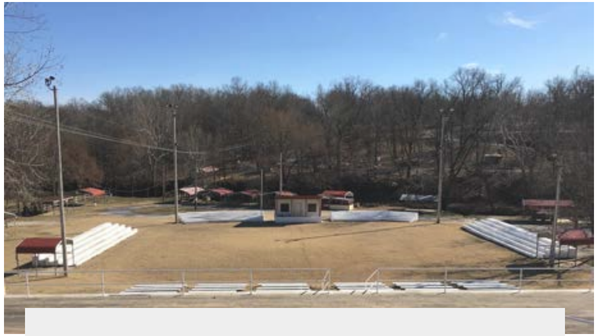
financing options

Everyone*! (*rural)	Tribes	Quapaw
Rural Energy for America Program	Tribal Energy Loan Guarantee Program (TELGP)	Tar Creek Superfund?

social goals

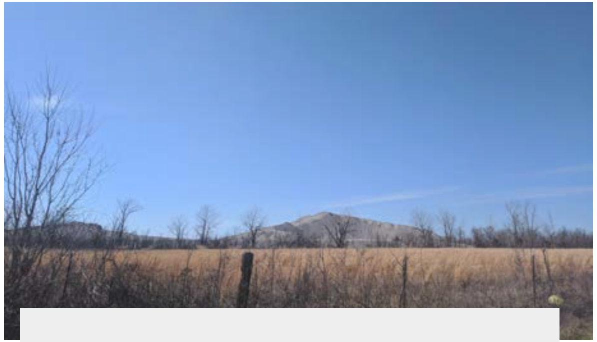
self sufficiency

live off the land



tribal member opportunities

job training / creation



re-imagine contaminated land

create environmental benefits

social benefits

rural waste
capacity building

renewables
capacity building

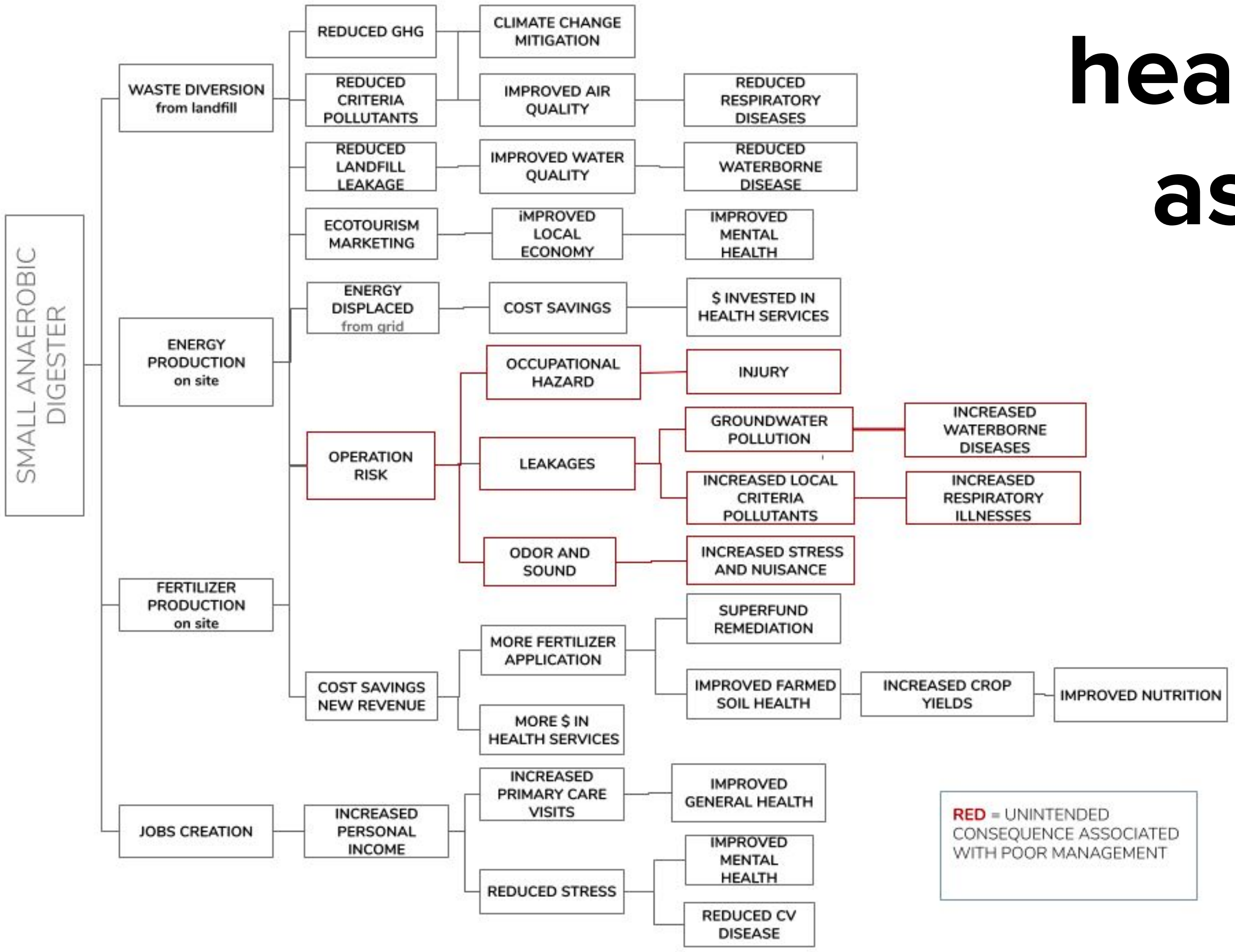
resilient community
leadership model

ghg reductions

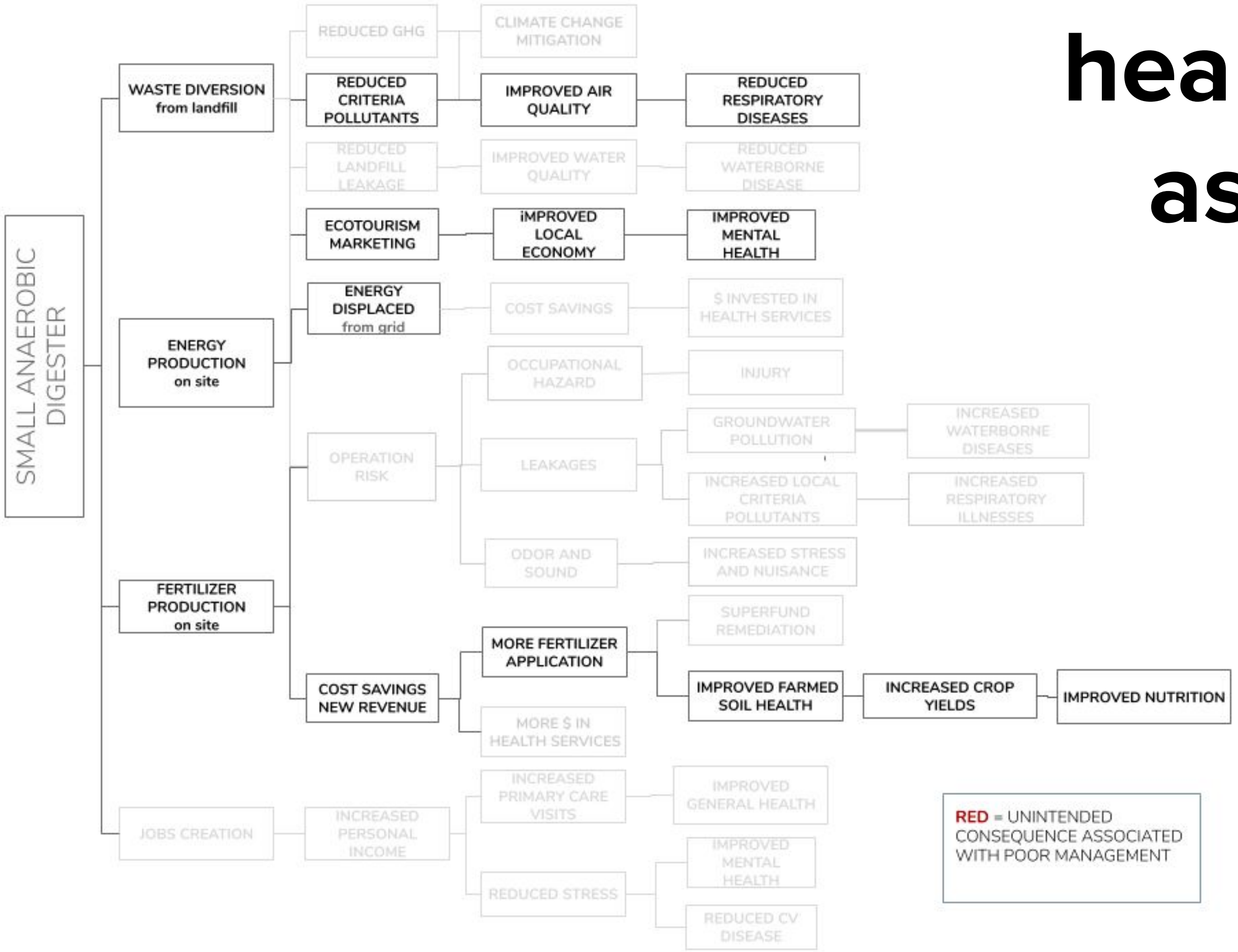
SOURCE	BUSINESS AS USUAL	GHG SAVINGS	
		PER YEAR (MT CO_2e)	LIFETIME (MT CO_2e)*
CASINO + COFFEE ROASTERY	landfill, methane capture & flare	**166**	**3,320**
MEAT PROCESSING	on-site septic treatment	**73**	**1,460**
ELECTRICITY SOURCE	oklahoma grid: 46% gas 26% wind 24% coal	**109**	**2,180**
REDUCTION/YEAR		**348**	**6,960**
SOCIAL COST OF CARBON ($84/TON)		**$32,172**	**$644,448**

**Assumes no change in source waste streams*

health impact assessment



health impact assessment



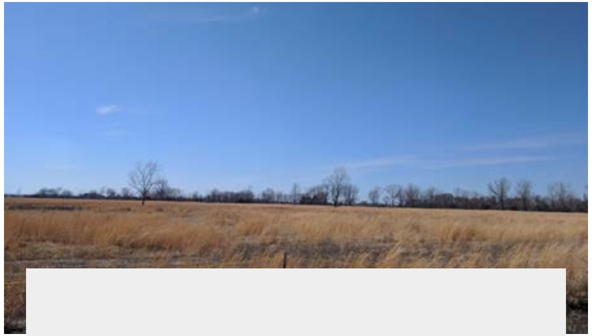
health pathways

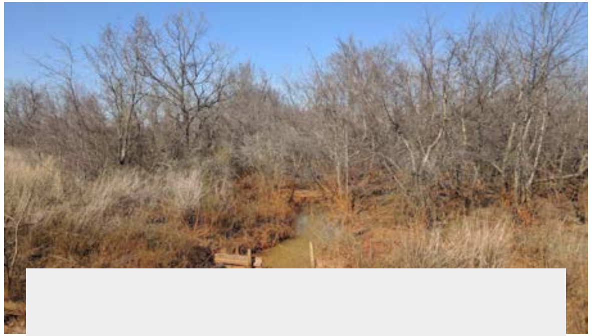
ENERGY DISPLACEMENT

WASTE DIVERSION

FERTILIZER PRODUCTION

health benefits





air quality
RESPIRATORY HEALTH

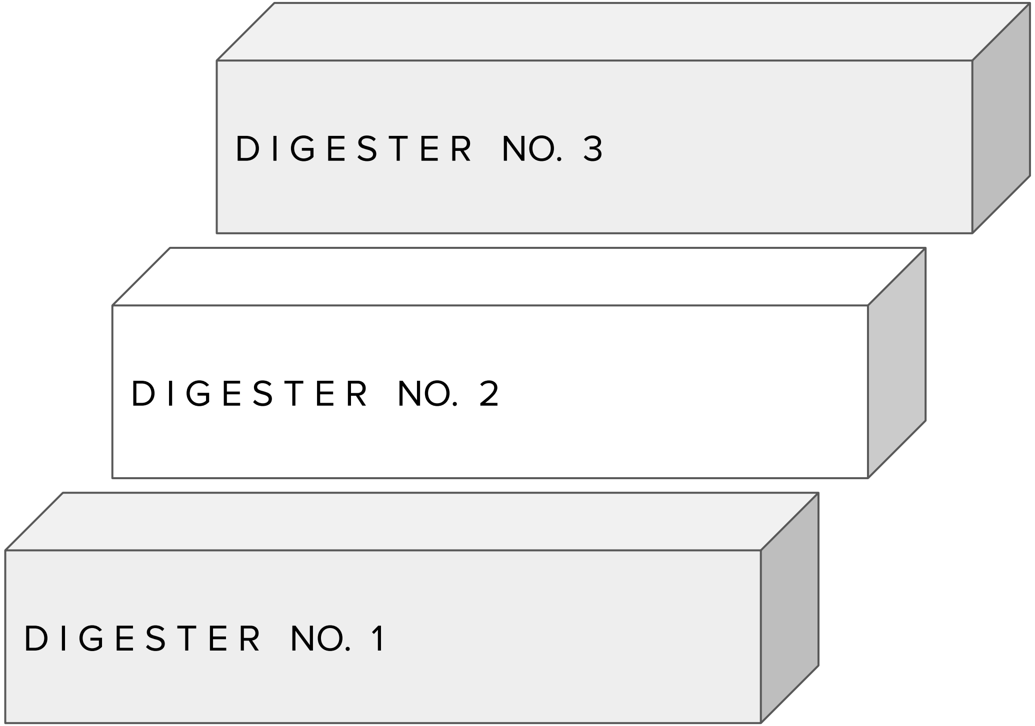
soil fertility
NUTRITION & FINANCIAL

stewardship
EDUCATION
MENTAL HEALTH

avoided consequences
noise, odor, leakage

site placement
mitigates risk

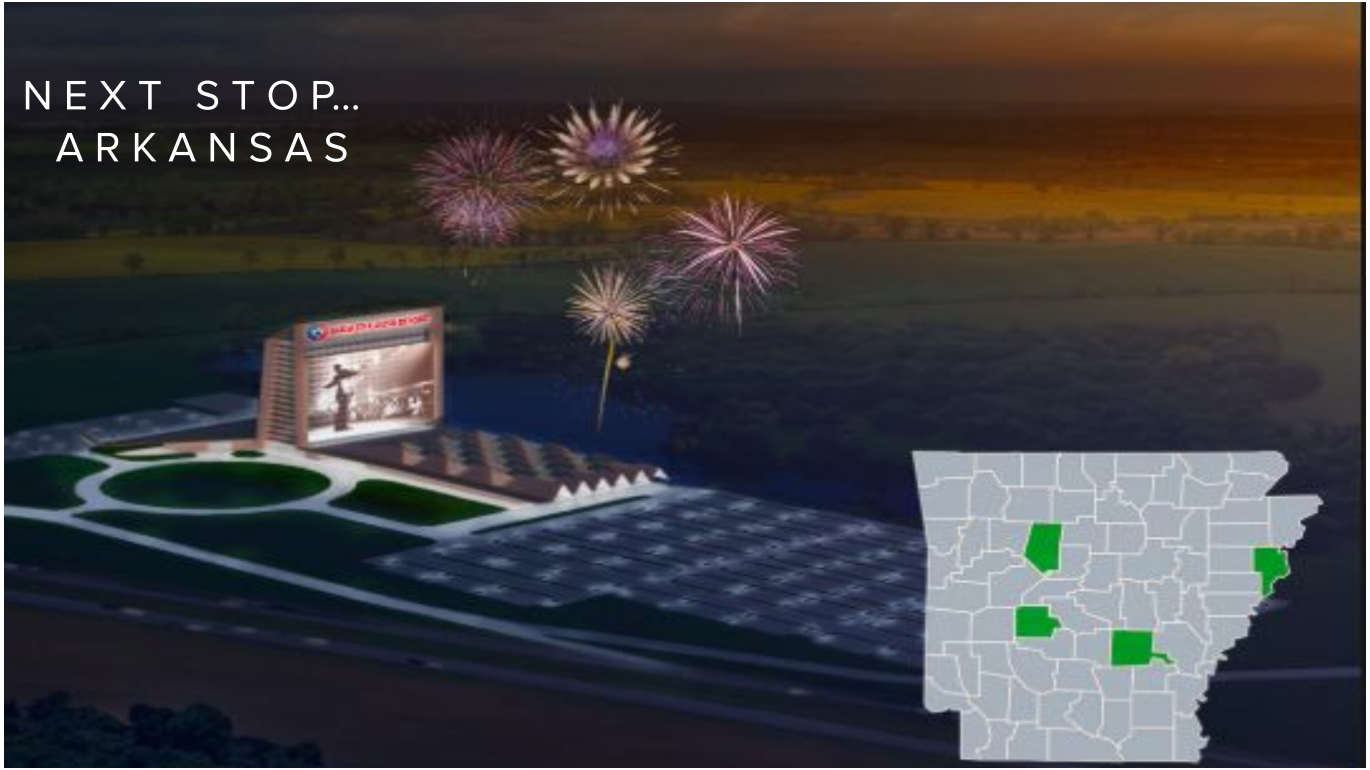
scalable



ON-SITE EXPANSION:

micro-digesters can build on each other, adapting to growing waste streams

replicable



replicable

HOTELS

STADIUMS

NATIONALLY

venues for
micro-digesters

UNIVERSITIES

HOSPITALS

next steps


COMPOST
ALL FOOD SCRAPS
COMPOSTABLE CONTAINERS
NAPKINS & PAPER TOWELS
TEA BAGS & COFFEE GROUNDS
(ALL PRODUCTS WITH THIS LOGO)


thank you
Q U A P A W