Sustainability Nexus for Standing Rock

Capstone Spring 2017

INDIANA UNIVERSITY SCHOOL OF PUBLIC AND ENVIRONMENTAL AFFAIRS

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Executive Summary

The Intertribal Council on Utility Policy (COUP) is leading an effort to maximize sustainability among the Great Plains tribes to both maximize benefits from current resources and to prepare the tribes for the changing climate. In the spring of 2017, the School of Public and Environmental Affairs (SPEA) at Indiana University collaborated with COUP to identify and assess the viability of solutions to sustainability issues in the intersecting areas of energy, food, housing, sewage, solid waste, water, and finance for communities in the Standing Rock Sioux Tribe. This project was undertaken by 18 graduate students in a capstone course under the guidance of Professor Diane Henshel. This capstone serves as the preliminary stage of an anticipated series of capstone collaborations between COUP and future IU-SPEA students. Future capstones are intended to further articulate and personalize sustainability recommendations for individual communities in the Standing Rock Sioux Tribe.

The focus communities for this stage of the anticipated multi-year collaboration are Fort Yates, Cannonball, and Mni Wiconi (a planned "eco-village"), each of which are located on the Standing Rock Sioux Reservation in southern North Dakota. The timing of this stage was unique, coinciding with the culmination of a months-long, on-site protest against the proposed route for the Dakota Access Pipeline. Over 10,000 protesters were reported to inhabit the Cannonball area, and—combined with the cause of the protest—demanded considerable attention and resources from previously-identified local contacts for this project.

The general recommendations for each focus area (energy, food, housing, sewage, solid waste, water, and finance) are as follows:

ENERGY

- Solar Power: According to stated assumptions, the most economically viable for a stand-alone photovoltaic solar panel system is an 18.6 kilowatt array which would produce roughly 21 percent of the assumed demand for the Eco-Village.
- Wind Power: According to stated assumptions, any wind installation that accounts for peak annual demand would be very economical, with a payback period of approximately five years.
- Battery Storage: According to stated assumptions, an arrangement that pairs wind-generated electricity with battery storage technologies merits further investigation. Battery storage of solar power is not economically or sustainably feasible at this time.
- Geothermal Heating: Geothermal heating and cooling is cost-effective and recommended.

FOOD

- Indoor Agriculture: According to stated assumptions, a greenhouse between 500 and 1000 square feet would cost $13,000 to $25,000 and is estimated to provide substantial nutritional benefits for the Mni Wiconi eco-village.
- Outdoor Agriculture:
    - Swales: Install swales for floodwater control and diversion to prevent erosion and flooding of farmlands.

- Prescribed burns: Manage prescribed burns of winter groundcover on a two- to three-year cycle to recharge soil nutrients and enhance the nutrition of livestock forage.
- Wind breaks: Plant a native evergreen tree species (i.e., Northern pine, *Pinus strobus*) three layers deep to protect crops and pollinator habitat from desiccation or physical disruption.
- Experimental orchards: Plant three trees each for six cold-hardy varieties of apple, pear, cherry, or peach. The yield of each variety can provide information on its suitability for local soil types and weather patterns.

HOUSING

- Straw Bale Housing: Straw-bale structures provide comfortable interiors, economical insulation, and energy efficiency—especially when designed to absorb solar energy as heat. They are not recommended for humid areas. The mid-range average cost is $115 per square foot.
- Earth Lodges: Stable internal temperatures of 50 to 60 degrees Fahrenheit can reduce utility costs. These lower-comfort structures are resistant to natural disasters and facilitate rainwater collection and solar panel installations. However, they are not recommended for areas that may experience flooding, and may be costly and complex to build. The average cost is $10 per square foot.
- Container Houses: Widely-available storage containers provide pre-made structures for these lower-comfort houses. Fast to install, mobile, and durable, they have an average cost of $65 per square foot.

SEWAGE

- Compost Toilets: Compost toilets reduce water use, exploit aerobic bacterial processes to reduce human waste in volume by 90 percent, and produce compostable matter. Per federal regulations, further treatment of the converted waste is necessary to avoid health hazards. User-acceptance can be a challenge. A commercial-grade, large-capacity toilet on average serves 28 people per day and costs about $6,000.
- Anaerobic Digesters: Standalone anaerobic digesters are scalable from household to community levels and can effectively process human, animal, crop, and food wastes. The biogas produced during breakdown is up to 75 percent methane (CH4), which can be captured and used as an energy source.

SOLID WASTE

- Landfills: Proper, legal disposal of solid waste is hindered by inadequate access to existing landfills. The Tribal Integrated Waste Management Plan provides a regulatory structure and policy goals from which to develop a waste management strategy. Site-specific data on the volume and content of peak loads are necessary before informed recommendations can be developed. The Tribal Solid Waste Program Costing Tool, published by the USEPA, may be valuable in a later stage.
- Open Dumping: The practice of discarding garbage in "open dumps" is an established practice due to poor connectivity to sanitary landfills, as well as a lack of understanding of more sustainable options. Public outreach brochures can

educate the community regarding different classes of waste and appropriate methods of disposal for each.

WATER

- Household Plumbing Upgrades:
    - Low-Flow Toilets: Replacement of a conventional toilet with a low-flush toilet can reduce water consumption from 3.5 gallons per flush to 1.28 gallons per flush. During the life of the unit, a family can conserve 13,000 gallons of water and $2,200 ($110 annually).
    - Faucet Aerators: Standard faucets produce a flow of 2.2 gallons per minute. Aerators can reduce this flow by 30 percent and provide annual savings of $15.36 per faucet.
    - Low-Flow Shower Heads: Standard heads use 2.5 gallons per minute; this can be reduced to 2 gallons per minute or less, and provide savings of 7,300 gallons and $100 annually per shower head.
- Graywater: Used water from household sinks, showers, bathtubs, and washing machines can be reused to irrigate nearby plants. Laundry drum, laundry-to-landscape, and branched-drain plans can be customized on a household-by-household basis, resulting in lower burdens on septic systems, decreased water bills, and conservation of potable water. The installation of such systems can cost in the low hundreds to the low thousands of dollars.
- Private Well Construction: Given adequate access to groundwater, residential wells would enhance water sovereignty. Cable tools are suitable for drilling wells in most geological conditions and require minimal manpower. Installation costs can range in the thousands of dollars.
- Rain Barrels: Rain barrels collect rain that concentrates on structures like roofs, and can be easily scalable from the personal garden to the greenhouse level. They can be fitted with gravity-powered irrigation lines or used to refill watering cans. Installation costs are less than $100 upwards.

FINANCE

- Mni Wiconi Eco-Village: Sustainability measures at Mni Wiconi can be funded by $3 million that has been earmarked by the Standing Rock Tribal Council for that community.
- Small Projects: Online crowdfunding platforms can be used to recruit donations for the implementation of sustainability improvements
- Further Recommendations:
    - Develop a time-sensitive, cost-effective analysis of desired improvements.
    - Apply for Tribal Economic Development (TED) bonds for sustainable development efforts that promote private economic development. These bonds are tax-exempt and are backed by a $2 billion maximum fund for distribution among all tribes, per the 2009 American Recovery and Reinvestment Act.

In sum, this capstone has identified numerous educational resources and possible routes to promote sustainability among the primary communities of Fort Yates, Cannonball, and Mni

Wiconi, North Dakota. At first look, the target areas of energy, food, housing, sewage, solid waste, water, and finance each present management opportunities that can increase resource independence. It is hoped that the findings presented below are of value—both to our clients in COUP, who hold as a critical goal the improvement of sustainable resource management at the community level, and to future SPEA capstone participants who seek to add depth and specificity to the broad recommendations that we provide here. The nexus of these areas is obvious at times (i.e., between water conservation and food production) and at other times, obscured by lack of understanding (i.e., with solid waste management). Further comprehension of the individual components of this system will heighten understanding of what constitutes the nexus, and in turn, how it can be most efficiently and sustainably managed across the Great Plains tribes.

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Introduction

This report is a response to the Intertribal Council on Utility Policy's (COUP) request for best practices at the nexus of sustainability for Cannonball, Fort Yates, and the proposed eco-village Mni Wiconi at the Standing Rock Sioux Reservation. The scope of the analysis of this nexus includes the best practices and their implications on the community for energy, food, housing, sewage, solid waste, water, and finance.

Based on these factors, the capstone class sought to promote tribal sustainability and independence by developing a community-based plan. The energy chapter provides a cost-benefit analysis of renewable solar, wind, and geothermal energy sources. The chapter on food provides best practices for the Mni Wiconi eco-village to become a center for healthy tribal foods that improve the health of Standing Rock, its members, and the land. The chapter on housing prioritizes eco-friendliness and cost-effectiveness by laying out three housing options including straw bales, earth lodges, and container houses. This report promotes sustainable sewage management for Mni Wiconi through an analysis of the pros and cons of compost toilets and anaerobic digesters. The purpose of the chapter on solid waste management is to create a sense of sustainable living in the Mni Wiconi eco-village and existing communities through efficient solid waste management. The chapter on water seeks to promote self-reliance from natural water sources and increase efficiency of water drawn from municipal water systems through upgrades to household water fixtures, reuse of greywater for garden irrigation, construction of private wells to promote self-reliance, and use of rain barrels. Finally, the report concludes with a chapter on financial mechanisms the tribe can use to pay for the recommendations made throughout the rest of the report.

Energy

Introduction

For this section, we looked at case studies detailing various renewable energy projects on other tribal lands. Most of what we found were suitability studies matched with cost studies for various system capacities for solar and wind installations. However, we did not find much in the way of actual, operational renewable energy facilities on tribal lands. We also conducted cost-benefit analyses for wind and solar systems capable of servicing the Eco-Village. We looked at geothermal heating and found through various case studies that is would likely be a good option for the Eco-Village. Finally, we make a few recommendations moving forward with the Eco-Village as well as how this study could be replicated elsewhere for communities like Cannonball or Fort Yates.

Solar/Battery Backup

Solar energy is one of the fastest growing energy technologies of the past five years. In states with net-metering policies and in areas serviced by utility companies with feed-in tariffs, distributed residential solar energy is becoming more and more appealing for electricity consumers given its ROI. Utility-scale photovoltaic (PV) solar plants are even more cost effective thanks to the economy-of-scale phenomenon, in which larger orders of various materials needed in a PV system (panels, racking system, inverters, etc.) allow for more efficient—and therefore cheaper—manufacturing and use of said materials.

Tribes have begun investigating solar energy as a source of affordable, reliable, and self-sufficient energy. The Washoe Tribe of Nevada and California used federal funding to develop a comprehensive report on the suitability of alternative energy. The report found a dispersed solar system to be the best fit in terms of economic and cultural value. The projected total cost for a 450 kW dispersed solar system in the Washoe Tribe's land is $1.35 million. Their expected simple payback time on the system is between 3.9 and 10.7 years, depending on the availability of tax credits and grants to discount the total initial investment (Johnson, 2014).

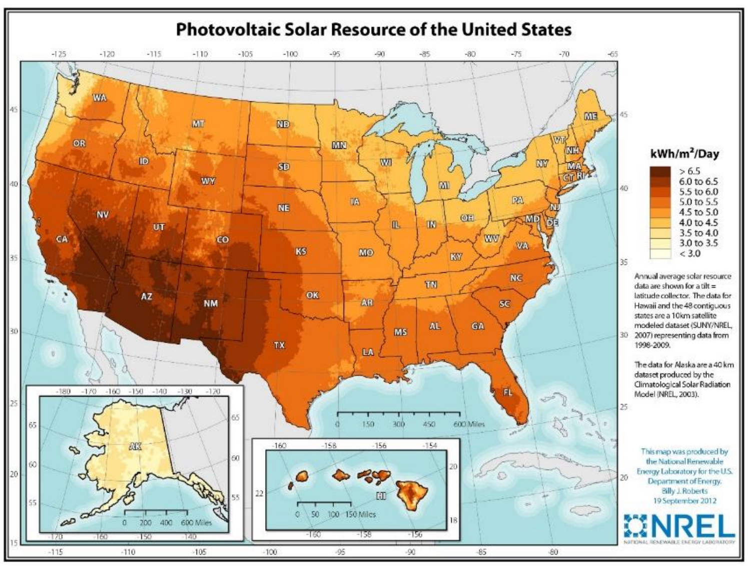


Figure 1. Solar potential across the US

The required investment and expected payback period for a solar system for the Standing Rock Sioux Tribe will differ because the cost of solar systems has decreased over time and differences in solar resource availability. The availability of tax credits and grants has changed since the Washoe Tribe's report was generated, and will continue to change in the future.

Utility-level solar generation was not feasible for the Washoe Tribe because of the increased complexity and necessary expenditure. Smaller-scale solar systems in the Washoe Tribe would qualify for net metering (Johnson, 2014); however, net metering may not be available to areas within the Standing Rock Sioux Tribe.

Larger-scale solar projects were considered in an energy report for the Pascua Yaqui Tribe. One project had costs in excess of $64 million. This project would include connecting a 20 MW solar voltaic system to the utility grid. This costs includes tax credits and financing options that may no longer be available. The suitability of the plan also relied on a high local demand and agreements with neighboring utilities (Arvayo, 2014).

Findings for the Eco-Village

For photovoltaic (PV) solar, a study by NREL released in 2015 shows a 50% decrease in price since 2009[1]. For residential systems that average five kW in size, costs are just below $3.00/Watt. For commercial systems averaging 200 kW in size, costs are around $2.16/kW and vary in price by region by about $0.15/kW from a base of $2.16/kW.[2]

With this in mind, we can calculate various pay-back periods for differing stand-alone and grid-connected system sizes. It should be noted that our payback periods take into account the time value of money (in the form of a discount rate, while the simple payback periods given in the introduction do not). Therefore, the payback period detailed below is a more realistic depiction of the benefits and costs of installing a system. For the Eco-Village, we made a few assumptions to help make the calculation simpler:

1. <u>Average State Utility Rate</u>: $0.09/kWh for the state of North Dakota[3]
2. <u>Estimated Capacity Factor</u>: 22% for the state of North Dakota (meaning a solar system will only produce 22% of what it would produce if it were running at full capacity every hour of every day of the year).[4]
3. <u>Discount Rate</u>: 6% for PV solar projects – we discount because money is worth more today than it will be in the future. Six percent is an industry standard for discounting.
4. <u>Annual Utility Rate Increase</u>: We assume a 3% annual increase in utility rates for the state of North Dakota based on utility rate trends over the past 20 years.
5. <u>Annual Baseload for Eco-Village</u>: 500 maximum population with an average per capita consumption of 350 kWh/year. This puts the annual load at 175,000 kWh/year for this investigation.[5]
6. Assume a lithium ion battery storage system costs $300/kWh of storage capacity and a lead acid system costs $255/kWh of storage capacity. This value is then multiplied by the highest amount of excess energy that will be produced by a given system in one hour. (This excess energy would normally be sold to the grid at retail price).[6]

Knowing annual solar patterns allows for relatively accurate power estimates down to the hour for an average day in each season. Therefore, we can calculate how much power will be

[1] NREL. *US Photovoltaic Prices and Cost Breakdowns: Q1 2015 Benchmarks for Residential, Commercial, and Utility-Scale Systems.* 2015.
[2] ibid
[3] http://www.electricitylocal.com/states/north-dakota/
[4] http://euanmearns.com/solar-pv-capacity-factors-in-the-us-the-eia-data/
[5] This number should not be considered accurate and is purely a reasonable assumption for the purposes of this investigation.
[6] http://www.nrel.gov/docs/fy16osti/64987.pdf

produced and at what point in the day it will be produced. We can take this information and pair it with historical (in this case, assumed) load reference data. From this, we can see which system size would allow for maximal benefit from a stand-alone PV solar array without wasting any excess energy. For the Eco-Village, it seems as though there may not be year-round occupants. However, for this investigation we will assume that an annual base-load is present (as mentioned above). Given the previously listed assumptions, as well as assuming that daily demand loads follow those we obtained from a utility company in the Northwest, we calculated payback periods for three system sizes based on estimated annual production. Our findings are summarized in Table 1.

In the third and fourth scenarios, maximum excess energy produced was found to be 480 kWh. This translates to a cost for the lithium ion battery storage system of: 480 kWh x $300/kWh = $144,000.

Predicted costs for the lead acid battery system are: 480 kWh x $255/kWh = $122,400. Generally, based on our previously mentioned assumptions, the only system size without interconnection that makes sense is the 18.6 kW system. As seen in Table 1, battery storage technologies, while able to capture excess energy that would normally be sold to the grid, drastically increase capital costs rendering the system too expensive to ever be paid off. However, if sustainability is the goal and funds as high as $400,000 can be allocated to a paired solar and battery storage system, it might be a worthwhile pursuit. This will be elaborated on further in the Conclusions and Recommendations section.

Table 1. Three scenarios for PV solar for the SRST Eco-Village project without interconnection to the grid. ROI refers to Return on Investment or the time it takes to recover all capital costs.

Stand Alone PV Solar Array						
System Capacity (kW)	Cost ($/Watt)	Capital Cost ($)	Annual Production (kWh/yr)	First Year Savings ($/yr)	ROI (yr)	Energy Offset
18.6	$ 2.00	$ 37,200.00	35845.92	$ 3,226.13	10	21%
	$ 2.16	$ 40,176.00	35845.92	$ 3,226.13	11	21%
	$ 2.50	$ 46,500.00	35845.92	$ 3,226.13	13	21%
90.8	$ 2.00	$ 181,600.00	174989.76	$ 5,045.00	N/A	35%
	$ 2.16	$ 196,128.00	174989.76	$ 5,045.00	N/A	35%
	$ 2.50	$ 227,000.00	174989.76	$ 5,045.00	N/A	35%
90.8 With lithium Ion Battery Storage	$ 2.00	$ 325,734.35	174989.76	$ 14,483.00	39	100%
	$ 2.16	$ 340,263.20	174989.76	$ 14,483.00	43	100%
	$ 2.50	$ 371,137.00	174989.76	$ 14,483.00	N/A	100%
90.8 With Lead Acid Battery Storage	$ 2.00	$ 304,115.79	174989.76	$ 14,483.00	35	100%
	$ 2.16	$ 318,644.64	174989.76	$ 14,483.00	38	100%
	$ 2.50	$ 349,518.45	174989.76	$ 14,483.00	46	100%

Conclusions and Recommendations

As is summarized in Table 1 above, installing a standalone system that does not connect to the grid drastically reduces the system's economic viability. The first system in the table, at 18.6 kW, would provide roughly 21% of the assumed annual demand (that system size was calculated so as to ensure peak production never went above consumption). Therefore, every kWh produced by this system would be used and can be accounted for in savings calculations.

The 90.8 kW system would produce the same amount of energy annually as the Eco-Village might consume. However, much of what is produced by such a large system is not used because peak production does not match peak consumption. Therefore, without interconnection to the grid and fair compensation for excess energy produced at any given time, only 35% of the total energy produced would go toward offsetting consumption and would accordingly be viable for savings calculations. This causes annual savings to be very low while the capital cost is still high. A system such as this would not be very practical and would never be paid off.

The third option adds battery storage as an alternative to grid storage through interconnection. While it is true that, with this option, all the energy produced would be used and the system would be able to account for demand at all times, the capital cost nearly doubles when battery storage is added. This negates any added benefit. With a warranty and typical lifespan of 25 years, this system would never be paid off.

Therefore, the best option with regard to economic viability for a stand-alone PV solar system would be an 18.6 kW array which, as described, would produce roughly 21% of the assumed demand for the Eco-Village in this investigation. As will be discussed in the next section, wind energy could be a viable complement to a smaller solar array.

Wind

As wind turbines become more efficient and cost effective, wind energy development will continue to increase exponentially. Due to these reasons, wind energy has increased its participation in the energy sector. As of 2016, 5.55% of all the generated electricity in the USA was from wind energy[7]. (Figure 2)

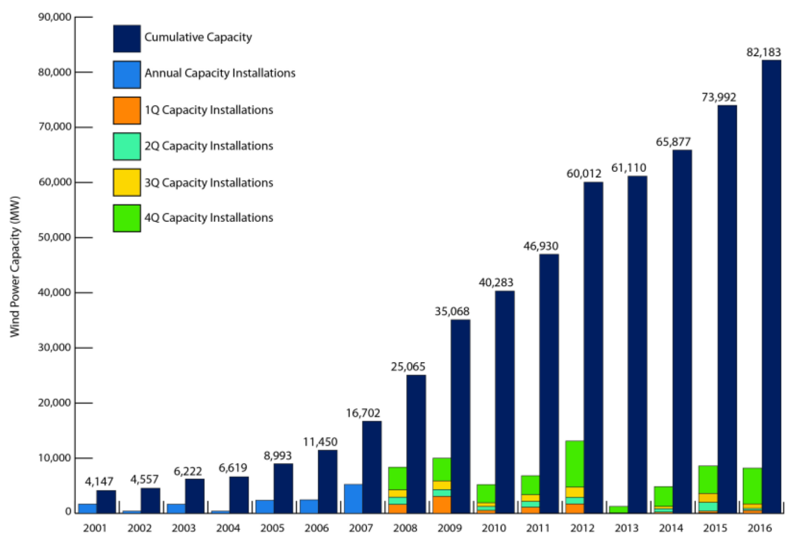


Figure 2. The growth of wind energy in the last years[8].

As a result of these trends, Native American tribes are also currently investigating if wind energy is a viable option for working toward tribal energy independence. The Washoe Tribe did not find wind suitable due to a lack of resource availability (Johnson, 2014).The Eastern Shoshone Tribe and Northern Arapahoe commissioned studies in Wyoming for large-scale wind generation suitability, but the project was deemed economically unviable because the wind resource availability in that part of the state is too low. The project also raised several concerns about harming endangered species (Stump, 2009).

The wind resources in Iowa are more comparable to those in the area of the Standing Rock Sioux Tribe. In a report on wind generation suitability for the Sac & Fox Tribe of the Mississippi in Iowa, installation of a 1.6 MW wind turbine was found to cost between $3.7 million and $4.0

[7] https://www.eia.gov/electricity/monthly/pdf/epm.pdf

[8] http://www.awea.org/wind-energy-facts-at-a-glance

million. This turbine would typically produce 5.7 million to 6.1 million kWh each year. The study estimated a simple payback period of 17 to 24 years, including annual maintenance costs, depending on developments in the cost of purchasing energy in the area (Lasley, 2013).

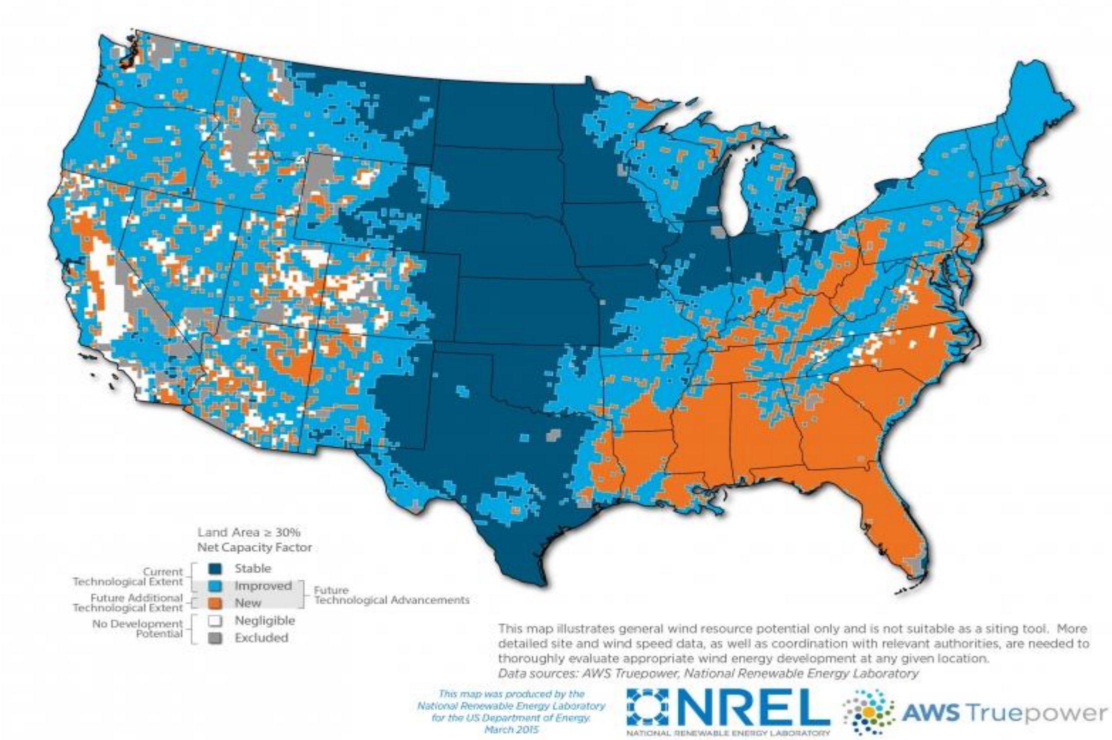


Figure 3. Wind resource potential (NREL, 2015).

Findings for the Eco-Village

Based on our annual demand assumption, we moved forward with a plan to install a wind power project with a capacity of 82.5 KW. This system would produce the same amount of energy annually as would be consumed. After deriving this information, we tried to find data about costs and capacity factor, as these factors will influence our final recommendations. The capacity factor at nearby regions was found to be 40% (WindAction); capital costs $1,690/KW (Hill); operations and maintenance costs $51/KW/year (Cost of Wind Energy). We also assumed a discount rate of 6.6% (unlike the simple payback periods in the introduction) to find the present value of the project, and assumed the predicted lifetime of a wind turbine to be 20 years (NREL Energy Analysis). After all these considerations and calculations, we arrived at a net present value for operation and maintenance costs of $49,030. When we add the capital costs of $139,425 for 82.5 KW, we arrive at a total cost of ***$188,455 for the entire project*.** Unlike the solar calculations, we could not accurately predict hourly and seasonal wind patterns and therefore could not accurately calculate a payback period for a non-grid connected system, or one that might produce energy at times when demand is not high and thus would be wasted. Therefore, the calculations above and the subsequent payback period of 5 years assumes all energy produced is either used or sold to the grid at the retail rate. In addition, we calculated capacities for up to 300 kW, which could be beneficial when considering wind energy projects with an assumed annual demand higher than what is proposed in this investigation.

Table 2. Wind energy project costs

Capacity (kw)	Total capital costs	O&M costs (discounted)	Total costs of the project	Time of recuperation for capital costs (years)
82.5	$139,425	$49,030	$188,455	5
100	$169,000	$59,430	$228,430	5
150	$253,500	$89,145	$342,645	5
200	$338,000	$118,861	$456,861	5
250	$422,500	$148,576	$571,076	5
300	$507,000	$178,291	$685,291	5

As a last source of information, we looked at potential zones that could serve as wind energy sites. Below are two images that show this information for the Standing Rock Sioux Tribe Reservation in North Dakota.

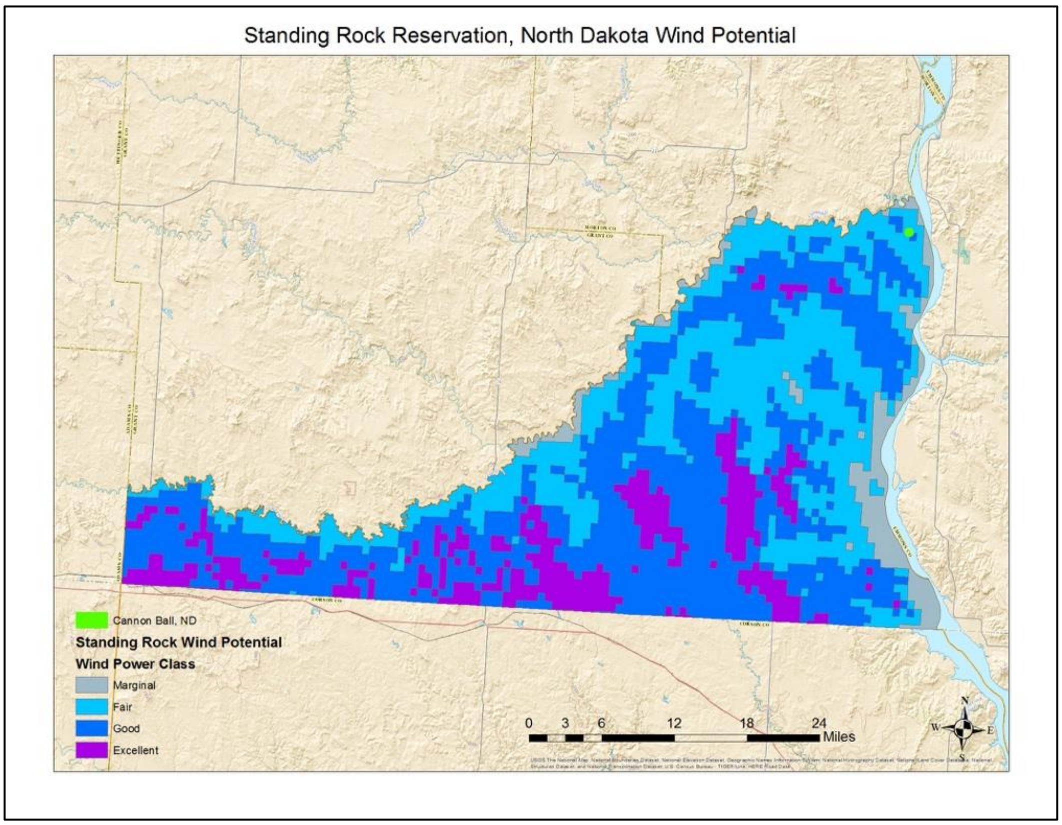


Figure 4. Wind energy potential in Standing Rock. Data taken from NREL (http://www.nrel.gov/gis/wind_detail.html)

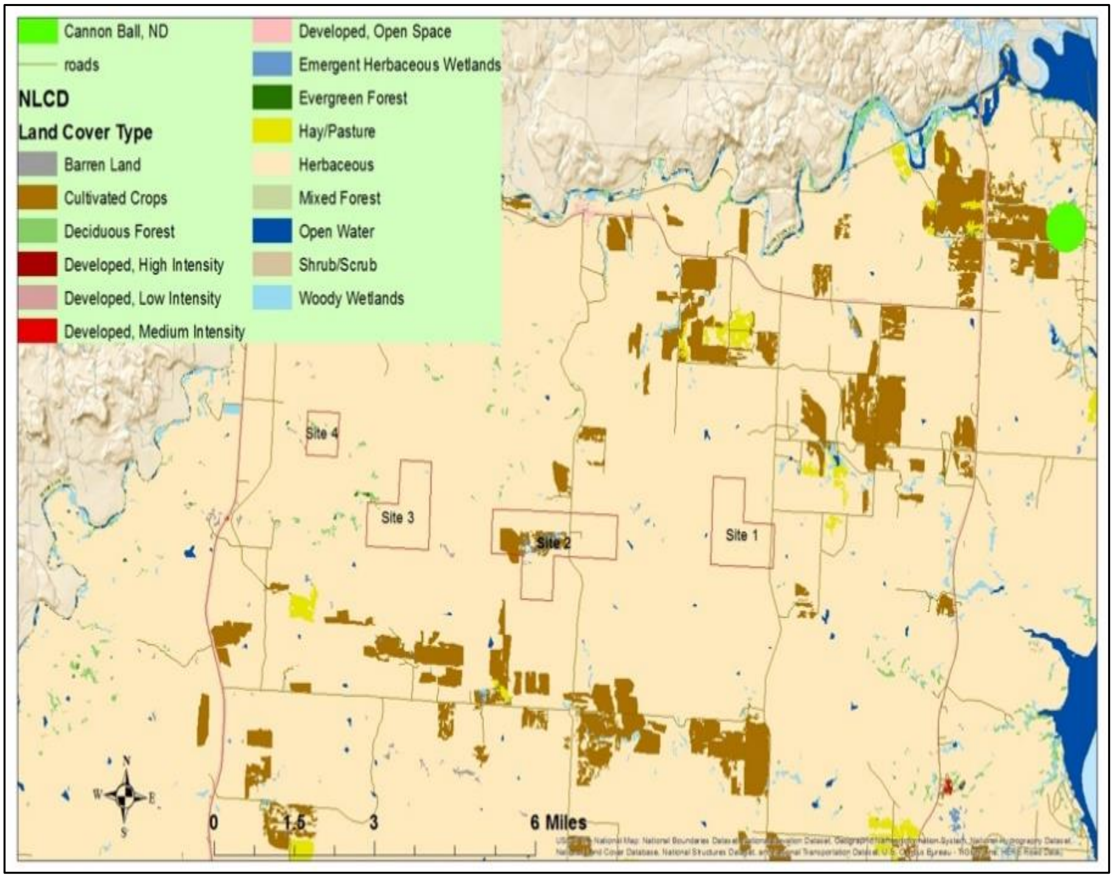


Figure 5. Potential wind turbine deployment sites for Category 5 wind energy potentials Cannonball, ND.

Conclusions and Recommendations

The calculations for wind were restricted due to the unavailability of information about wind energy outputs in regions close to the Eco-Villages proposed location. Wind patterns are very difficult to forecast and therefore make it virtually impossible to accurately match up hourly and daily production with demand. However, with the provided information, we arrived at results which should serve as a point of reference for decisions regarding energy projects in the future. At this time, for wind, virtually any installed capacity accounting for at most the peak annual demand would be very economical, with payback periods of around five years (assuming that interconnection or consumption behavioral changes match production). Again, because we were unable to calculate discrepancies between production and demand, we have assumed that all production will be used. However, as payback periods for wind projects are already quite low, it may be worthwhile to investigate pairing wind with battery storage technologies to ensure this is in fact the case if it is not interconnected with the grid. Unlike solar, a wind farm capable of producing all energy needed to power the Eco-Village paired with a battery storage system might be economical as well as sustainable.

Case Study Analysis for Geothermal Heating/Cooling

In general, utility-grade geothermal generation is not suitable for the Standing Rock Sioux Tribe. It would suffer from the same problems as other tribes (such as the Washoe Tribe) that lack this resource availability (Johnson, 2014).

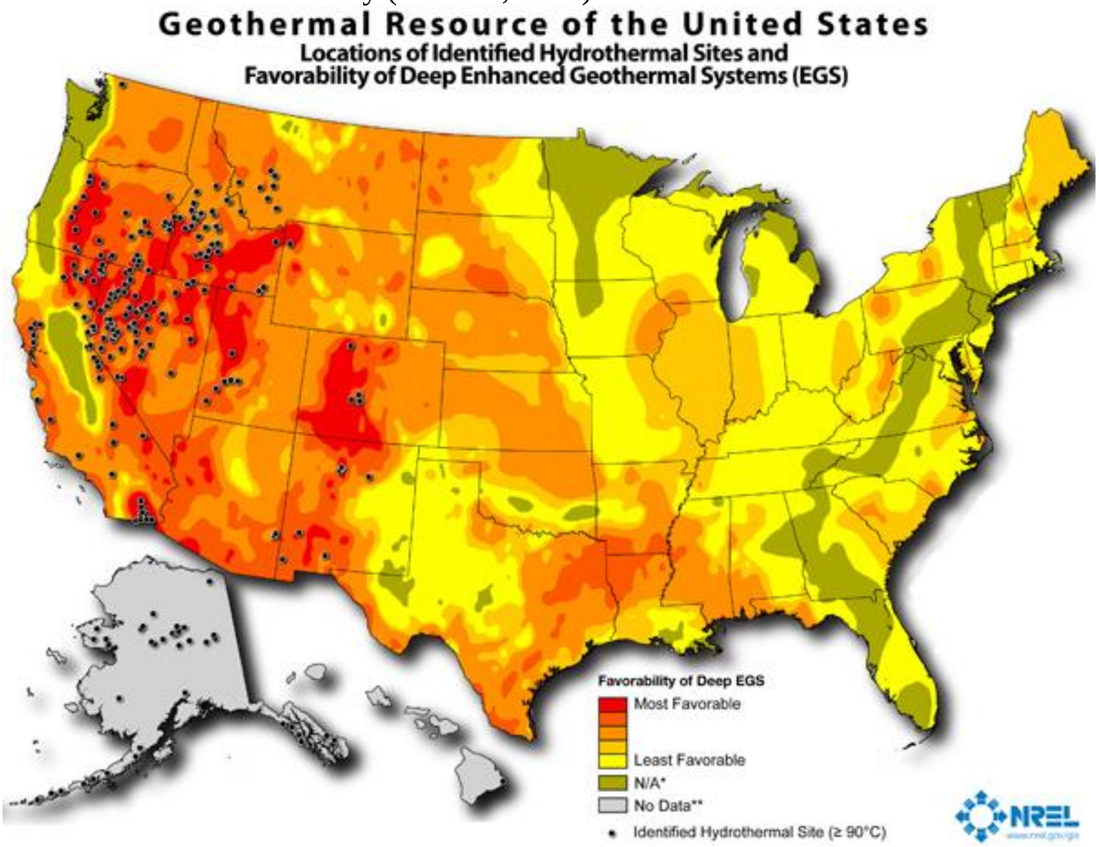


Figure 6. Locations of identified Hydrothermal Sites and favorability of EGS (NREL, 2011)

Geothermal indoor heating and cooling may be a more practical system to develop. When using a geothermal heat pump, the soil, land availability, and hydrology of each site must be considered. The exact costs of a system depends on the size of the building under consideration, and the heat loss from that building. Each ton of capacity is equal to 12,000 BTU per hour, and each ton of installed capacity can vary widely in cost. The cost savings of the system depend on the type of system that it is replacing, but the systems generally pay for themselves in five to 10 years (Energy.gov).

In a feasibility study for the Nez Perce Reservation, the Geo-Heat Center, run by the Oregon Institute of Technology, investigated the viability of installing a geothermal heat pump in a middle-high school that was under construction. They found that adding a geothermal heat pump would add approximately $114,000 in capital costs, but decrease annual utility costs by approximately $17,000. The geothermal system also had lower periodic replacement costs than conventional heating equipment, and a simple payback period of 6.5 years. Over a 50-year life cycle, the geothermal system is expected to cost approximately $250,000 less in net present value, representing a savings of 25% over conventional heating (Chiasson, 2006).

In another study by the Geo-Heat Center, they found favorable results for geothermal heat pumps to be built at the Coeur d'Alene Tribe's new cultural center. The Geo-Heat Center found that the lowest-costing geothermal heat pump system could add $72,750 to the capital costs compared with a conventional system, but provided annual energy savings of $10,400. This amounts to a simple payback period of approximately seven years (Lund, Chiasson, & Boyd., 2006).

Case Study Analysis for Building Upgrades

Many tribes have found that they may benefit from building upgrades that would reduce energy consumption. These projects can occur at a variety of scales and costs.

Energy audits for the Oneida Tribe of in Wisconsin found that energy improvements in 44 buildings owned by the Oneida nation could save 3,700,000 kWh of energy and provide significant thermal improvements. Many relatively low-cost projects such as weatherization, water heater replacement, and lighting changes were found to have a return on investment of less than five years. Large cost projects, such as facility-wide window replacements, were found to have larger savings, but often had longer timelines for return on investment (Schubert, 2014).

The Nez Perce Tribe also found that building upgrades could make large improvements in energy efficiency after finding that energy costs were taking up a significant portion of their operating budget. Lighting fixture changes, window upgrades, and insulation upgrades made buildings more comfortable and significantly reduced energy costs. Partial funding was available through the Department of Energy and an incentive program run by their local energy utility (Kinder, 2012).

Further Implications

Because relatively little is known about load information for the Eco-Village, it is difficult to give accurate estimates of cost recovery and necessary system capacities for any energy projects servicing the village. However, further investigations could analyze historical load data for communities within the reservation such as Cannonball or Fort Yates. With this information, relatively accurate estimates could be made allowing for informed decisions about whether to move forward with renewable energy projects for these communities. For both communities, most energy needs could either be met with distributed solar on homes or a centralized field of panels paired with a centralized wind farm. If behavior within the communities could then be adapted such that peak consumption matches peak production, the communities could become completely self-sufficient without any reliance on outside utility companies (which are subject to changing rate structures and generally increasing rates as time moves forward). New construction should consider geothermal heat pumps to reduce energy costs, while existing structures may benefit from a number of small and large upgrades to increase energy savings.

Food

Introduction

The COUP has stated their wishes for the Mni Wiconi Eco-Village to be a center for local, tribal food revolution that promotes health and wellness for the community. The hope is for Mni Wiconi to become an education hub and plant nursery to promote healthy eating in the village and the surrounding communities. The proposed actions in this chapter seek to reduce the reliance on processed foods that have led to an epidemic of diet-related illnesses like diabetes and a dependency on federal food systems that threaten tribal sovereignty. This chapter provides best practices and costing information on land management, infrastructure and production, and healthy food education.

Sustainable Forestry Management Practices: Best Practices

Use swales as land use form for flood control and diversion

Using swales for flood control and diversion for water storage can protect perennial crops, including orchards and timber stands. Standing Rock needs to adapt to seasonal flooding from snow melt and summer storms. This is especially true at the Sacred Stone Camp site. Swales divert water more evenly across a broader swath of land. Heavy rains and flooding can uproot trees and pose a great risk to getting peak production out of a food forest. It just so happens that the soil extracted from making swales create a berm, which are great for planting trees. In early growth trees, ground plants (e.g strawberries) and medicinal plants could be in production at the base of this nutrient rich, moist soil.

Manage prescribed burns every two to three winters

These burns restore native prairie grasses and flowers, attracting critical pollinators and subduing invasives. A burn in the winter would help native warm season grasses take hold since invasives are cool season grasses. Follow a prescribed burn by a direct seeding for ground flora with hand broadcasting to reduce compacting of the soil.

Mob grazing

Mob grazing for livestock could be used in the fall following a prescribed burn since ruminants like greener, sugar-rich grasses. A hunting strategy could also be used in the year following a patch burn, a more localized form of a prescribed burn, by attracting deer and other ungulates that also like the greener grasses.

Wind breaks

Develop wind breaks to reduce desiccation of hardy trees and improve pollinator habitat First, figure out where the wind is coming from. Then, plant three layers of a native evergreen species (e.g. Northern Pine), which can take a beating from wind. On the internal side of the break, create wild pollinator habitat and/or develop an apiary. This would also be a place to develop ground flora (e.g. native herbs, such as *Echinacea angustifolia*), hardy native crops (e.g. prairie turnip), and mushrooms. If any machinery is being used on the land, make sure the wind breaks allow for passage in some areas.

Experimental orchards

Start with cold, hardy varieties of fruit trees: apple, pear, cherry, and peach. Pick six varieties for each fruit and get three individuals of each variety. Make sure planting is complementary. For example, X tree needs Y number of flowering individuals to fruit. Maintain careful records of their development. Make sure to use fencing for animals and raking to prevent jumps in the prescribed burns. As they reach peak fruiting years, one will know which varieties to expand in mass. One could even take clippings from parent trees and develop an orchard nursery.

Critical Questions

- Does Standing Rock have retired or neglected agroforestry sites?
- Where is the land? Is the siting flexible?
  - Soil types?
  - Past land use (as far back as possible)? Current land use?
  - What grass (native? invasive?) is growing?
  - Any livestock? If so, do you practice mob grazing?
- Who is the champion of the food forest? Is that the same person who would manage the project?
  - What are their goals and objectives?
  - Who would be using the food forest?
- Is anyone seed saving prairie grasses?

Culture

The decline of traditional food systems among Native American communities has contributed to the rise of food insecurity and health problems. Low-income residents on reservations are eligible for the USDA's Food Distribution Program on Indian Reservations (FDPIR) as well as Supplemental Nutritional Assistance Program (SNAP), but it is not clear how many persons are eligible and how many are receiving.

Nutrition & Education

Diet-related illnesses have been shown to be a concern, particularly among Standing Rock elders. For example, a study conducted by the Standing Rock Nutrition for the Elders and the Standing Rock Elder Advisory Council found that "the incidence of Type II diabetes among Standing Rock elders is twice the national average," 46% as compared to 23%. (Ruelle 2011, 76).

United Tribes Technical College has a short-term training, adult learning certifications, and food degrees that focus on community health, nutrition, natural medicine, food service, and other topics. They are equipped with courses that are specific to the nutritional and community health needs of the Standing Rock Reservation citing specifically “experience, observational data, and lessons learned through exchange of verbal conversations." They are willing to provide short-term training through the UTTC Extension program that covers topics such as gardening, nutrition, food gathering/preparation/safety, coalition building, ethics in the workplace, financial management, cooking, et cetera.

Assets & Opportunities

Farmers markets have sprung up in recent years, including in Fort Yates. However, access to produced food locally is not universal across the reservation. While the markets participate in federal programs to increase attendance and profitability, high prices tend to deter the local population. See Chapter 3 of Ruelle's 2011 thesis for more analysis of food and access conditions and the appendix for particular plants. In addition, there are several initiatives from within and outside of Indian country to establish cooperative food businesses (see appendix for resources).

Concerns

Food insecurity has been a concern on the reservation. While the demographic data makes this plausible, we were unable to gather specific information about the spread of food insecurity and the dependency from federal food assistance. Qualitative accounts, however, indicate a high ratio of dependency on food assistance. So far it seems like FDPIR is used more than SNAP, but both are not sufficient. We are wondering if there is data available on imported food and money going off the reservation as well as more information on food preferences and availability in grocery stores on the reservation.

We briefly spoke to Lisa Colombe about school lunches on the Pine Ridge reservation and contacted Wanda Agnew at UTTC, but did not further pursue the topic due to the lack of connection and data. Dr. Agnew mentioned various challenges for food planning and nutrition training when collaborating with the tribe.

Greenhouses

Greenhouses typically cost $25 per square foot with an average cost of $13,893. A greenhouse should be a minimum size of 10x10 feet. A large size greenhouse that would feed the Mni Wiconi Eco-Village should be between 500 and 1000 square feet which would cost the tribe between $13,000 and $25,000 per greenhouse.

The tribe can choose glass, polyethylene, fiberglass, or polycarbonate siding. Glass siding costs about $2.50 per square foot and is durable and conducts heat well; however, it does not diffuse light which can burn plants and requires a strong frame. Polyethylene siding costs about $0.12 per square foot but must be replaced every two years. Fiberglass costs $72 per 6x8 foot panel and provides adequate light diffusion but can crack in heavy weather. Polycarbonate costs about $55 per 8x4 foot panel which insulates well, does not require a heavy frame, and protects from UV radiation but it scratches easily.

The tribe can choose from wood or steel framing. Wood costs about $1 per linear foot and is durable and naturally insulating but requires treatment to protect form insects and weathering. Steel framing costs $2.50 per linear foot and is low maintenance and durable but it draws heat away from the crops and is less customizable than wood.

There are also several different excavation options. Concrete costs about $10 per square foot and should contain texturing and drainage. Pavers cost between $8 and $11 per square foot. Gravel costs about $0.75-$3 per square foot but requires regular weeding. Additionally, the tribe should expect to spend $8000 on lighting and heating, ventilation, and air conditioning systems. Installation of grow lights should also be considered due to Standing Rock's decreased growing season. These grow lights cost between $30 and $130 each.

These costs are all estimates based on observed nationwide prices for greenhouse owners. These prices are not based on current market price in Standing Rock but the national average. By reusing salvaged materials, the tribe could save significantly on these materials.

Best Practices

In cold areas like Standing Rock, the main focus should be on increasing temperatures within the greenhouse. Greenhouse roofs should have a low slope to optimize sunlight. The greenhouse should face east to west with the crops running north to south to optimize ventilation and sunlight.

To conserve water, the greenhouses should utilize sustainable irrigation techniques. Drip irrigation conserves water and labor while reducing runoff. Punctured water hoses can be used to target the areas in the garden that need to be watered. Water trays or saucers that collect the water that drips from the pots can also be used to conserve water.

Integrated pest management can be used to reduce the amount of pests in the greenhouse without relying on herbicides or pesticides. Some common integrated pest management techniques include:

- Inspecting each plant that arrives to the greenhouse for weeds, algae, or pests
- Attaching yellow sticky cards to the plants to monitor winged pests
- Placing sliced potato disks to monitor fungus gnat larvae.

Food Options

Crops most commonly grown in greenhouses are those with medium thermal requirements like tomatoes, peppers, cucumbers, melons, green beans, and eggplant. These crops thrive in temperatures of 63°F to 82°F and should receive six hours of light per day on average.

Table 3. Plants Needed to Feed One Person Per Year.[9]

Artichokes	1-4	***Eggplant***	1
Asparagus	10-12	***Kale***	1 5’ row
Bush Beans	10-20	***Lettuce***	10-12
Lima Beans	10-20	***Melons***	2-6
Pole Beans	10-20	***Onions***	40-80
Beets	10-20	***Peas***	25-60
Broccoli	5-10	***Peppers***	5-6
Brussels Sprouts	2-8	***Potatoes***	10-30
Cabbage	3-10	***Pumpkins***	1
Carrots	10-40	***Rhubarb***	2-3
Cauliflower	3-5	***Spinach***	10-20
Celeriac	1-5	***Summer Squash***	2-4
Celery	3-8	***Winter Squash***	2
Corn	12-40	***Sweet Potatoes***	5
Cucumbers	3-5	***Tomatoes***	2-5

Conclusion

The preceding recommendations in this chapter are subject to alterations based on the specific needs of the Standing Rock Sioux community. What has been provided here is simply a framework with background information that could be helpful in the design process for the Mni Wiconi Eco-Village. To aid in the adaptability of these recommendations, resources and contacts from Standing Rock and other tribes are provided in the appendix of this report to assist in modifying these recommendations based on the specific needs of the tribe.

[9] http://www.wellfedhomestead.com/how-much-should-you-plant-in-your-garden-to-provide-a-years-worth-of-food

Housing

Introduction

Many environmentally conscious communities around the nation have embraced alternative housing options such as straw-bale housing, earth lodges, and even retrofitted shipping containers. These provide affordable habitation that reduces resource demands, rather than amplifying them. Tribes and reservations throughout the nation have realized the benefits of conservation by introducing housing solutions such as these. Standing Rock should consider alternative housing options to make the most of the efficiency solutions outlined throughout this document. The following information outlines the benefits and drawbacks of straw-bale housing, earth lodges, and retrofitted container housing.

Straw-Bale Housing

Straw bales are unconventional building materials made from leftovers of stems and harvested grains. The term is also used to refer to any dried plant residues that are compressed and baled. This building material is economic and environmentally friendly, and if utilized effectively, the building will be durable, energy efficient, fire resistance, and safe. Compared to conventional buildings, straw-bale houses are inexpensive, aesthetic, and relatively easy to build once the basic structuring is learned and materials are provisioned, making it a fit choice for do-it-yourselfers. Many straw-bale houses adopt an adobe exterior, which reflects a warm-looking and artistic environment. There are two general designs of straw-bale building, Post and Beam (also known as In-Fill) and Load Bearing; this report will discuss Load Bearing only. In spite of all the advantages straw has as a building material, it certainly has disadvantages that need to be addressed and mitigated. Both advantages and disadvantages shall be elaborated ahead with highlights on safety and durability, ease of construction, energy efficiencies, cost estimation, and environmental considerations.

Building Materials, Availability, and Approximate Costs

One of the advantages of straw-bale building is simplicity, which must also be reflected in the required materials to achieve the work. Below is a compact list of the needed materials with optional suggestions (full version available in appendices with approximate associated costs):

- Approved design blueprints and guides (International Building Council’s Building Code (ICC’s IBC))
- Straw bales (preferably 2-string units)
- Lumber for floor base, roof, and wall framing (or steel if preferred)
- Wood treatment against insects, moisture, and decay fungi
- Structural Materials, such as beams and studs, which could be made from recyclable woody materials.
- Engineered sheet materials (similar to plywood and MDF), which could be made from recycled wood
- Non-toxic termite control during the construction phase via physical controls such as sand barriers or metal termite shields
- Earth materials such as:
  - Stones and Bricks
  - Soils for rammed earth construction
  - Soil materials for flooring

- Floor coverings from recycled or reused materials such as padding and carpeting, water-based adhesives, tiles, and linoleum
- Roofing materials such as fiber-cement slates, asphalt shingles, and metal roofing products
- Windows and doors
- Interiors such as furniture and fixtures
- Paints, Finishes and Adhesives
- Personal Protective Equipment (PEE)

To serve the purpose of cost-efficiency and sustainability, it is more efficient to use straw bale from local sources as the shipping costs and pollution from transportation may partially compromise these benefits. Corn, oats, and alfalfa bales are available in abundance in North Dakota at affordable prices. For instance, straw and hay bales are sold online and in Bismarck for $20-$80 per ton and each ton serve around 30 2-string bales. Presumably 6-8 tons are needed to build a house, then the price of total bales would range from $480-$640. According to the Navajo tribe experience, a straw bale house including labor and material can cost $57,046. Those who build it themselves can save 15% of the total cost according to a straw bale building expert. However, exact housing cost is difficult to estimate without complete information. Estimations in appendices shall help with initial approximation.

Ease of Construction and Needed Skills

As mentioned above, Load-Bearing construction is selected for this report because of its simplicity of application. This style mainly depends on stacking bales firmly to prevent separation. To fix them more tightly, studs could be used between the stack layers in addition to interlocking the corners with the wooden frames. Compression of stacked straw walls is necessary along the process of building to prevent gaps as these gaps are highly undesirable for energy efficiency reasons, moist prevention, and fire resistance. Compression could be achieved through several means, but having a flat and straight surface shape is a good start. Using ropes to tighten stacks is common, and walking on the wall and using a large hammer is another tool for compression and leveling. With simple guidelines accompanied with general household work experience, a group of people can build a straw-bale house themselves without significant outside consulting. A Load-Bearing design as the name suggest bears loads and hence requires much less wood to support the roof structure, which would save costs and save building materials. The benefits of such experience is not limited to the physical structure of the house as such building exercises are also common in community building and volunteering projects, because it strengthens teamwork and enhances societal cohesion.

Durability, Health, and Safety

There are impressions about straw bales being susceptible to fire, wobbly, and prone to mold and infestation. Most of these are not true, but some are. Below are facts about straw-bale housing durability, health, and safety.

Straw as a biological material is sensitive to certain climatic features, such as rain and humidity. If straw bale walls are not properly protected, they can absorb moisture or become fully saturated with water, which is undesirable because it aids unhealthy mold and infestations. In addition, moisture makes straw bales expand, which could result in cracks in the structure, affecting its lifespan and durability. Moisture can also make the walls more susceptible to fire, which imposes physical, financial, and sentimental hazard. The key issue in the previous examples is moisture prevention, which is luckily something controllable during the construction phase. One prevention solution is to have a large and waterproofed overhanging roof and a large raised foundation for the house to ensure protection from top and bottom. It is safer to have the waterproof membrane extending a few inches further from the straw bales for increased protection. Humidity control is challenging as it penetrates walls regardless of roof and base structure. However, there are two suggestions to mitigate for humidity moisture. One is using hygroscopic plaster (e.g. lime) as it absorbs moisture and holds on to it, and once atmospheric humidity declines it releases excess moisture back into the air without allowing it to infiltrate into the straw bales. Second, Energy Recovery Ventilators (ERV) keep the air dry enough inside the house. In general, straw-bale houses are not the best option for extremely rainy and humid regions.

Susceptibility to fire is another initial concern when it comes to straw bale buildings. However, they are surprisingly more fire resistant compared to other building materials. Decomposition and oxygen propagate fire, but the bales are dead and dry materials preventing decomposition caused by moisture. They are also compacted and airtight with no gaps allowing little oxygen to exist in pores, which does not aggravate the fire and aids its containment.

Another health and safety factor to be taken into consideration during the construction phase is to ensure rats and other pests remain out of straw materials before final insulation to protect the structure and house residents.

Efficiencies and Environmental Considerations

Straw bale houses are popular sustainable and energy-efficient buildings. Their thermal insulation characteristics along with passive solar construction design make cooling and heating inexpensive for straw bale house owners and society. In other words, these houses would have low upfront costs and even lower long-run costs. The R-value, a measure of insulating quality, of compressed straw bale ranges from 17 to 55 in which higher R-values are better in quality (American Unites). Compressed and plastered straw bale walls are excellent for thermal insulation and fire resistance. Research done in Arizona found that wheat and rice straw bales have insulation powers ten times higher than double-brick cavity walls. In the face of climate change, energy efficiency reduces demand of energy and fossil fuels. (More energy efficiency recommendations for water, lighting, structural design and other useful resources available in appendices).

Straw production is also more sustainable than timber production. Straw is a byproduct of agricultural activities that already exist and the excess is usually burnt. In the US, 200 million tons of waste straw are produced every year, and every 1 million tons burned can release around 56,000 tons of carbon dioxide. The reuse and recycling of such material will offset these emissions and will also reduce dependence on timber harvesting, which contributes to climate change as trees and forests are biological carbon sinks. Using straw as a building material is beneficial to the environment and the economy. For instance, around 40% of the world’s wood, minerals, water, and energy is used in the manufacturing and transportation of building materials. It is important not to engage in land conversion to produce straw as this will lead to the same controversy of biofuels and bioenergy.

Earth Lodges

Earth lodges offer many benefits that are environmentally friendly and low cost in comparison to traditional housing design. Aside from the reduced cost and complexity of building materials and labor, earth lodges are designed to reduce heating and cooling costs by maintaining temperature stability. Average temperatures for underground facilities fluctuate from about 50 to 60°F, while bermed facilities (earth lodges with part of the exterior or roof unburied) will sacrifice temperature stability for increased natural lighting. Earth lodges require very little maintenance to the exterior of the structure and have even been proven to be more resistant to natural disaster such as tornadoes or severe storms so long as the structure is built outside of flood plains. In fact, some insurance companies give more favorable rates to earth lodge owners due to earth lodge resilience in times of dangerous weather and because fewer flammable materials are used in earth lodge construction. Earth lodges also afford cultural benefits as Native American tribes have been constructing and perfecting earth lodges for thousands of years, which may make living in earth lodges more appealing for residents and visitors who recognize the cultural meaning behind earth lodge housing.

Naturally, earth lodges have several disadvantages to offset some of their advantages. Earth lodges typically have poor lighting due to reduced windows, although this can be mitigated by using bermed designs. Careful water proofing of the exterior is important so that water seeping into the living area can be avoided, which adds to the cost and complexity of earth lodge construction and reduces the biodegradability of construction materials. Due to the lower temperature in earth lodges, condensation may be more likely to condense on interior walls, causing mold and structural concerns. While this can be fixed with dehumidifiers and proper insulation, this still adds to cost and complexity. Ventilation may also be an issue in lieu of proper design. Earth lodges do not lend themselves to having more than one exit in the case of an emergency, such as a heavy snow or fire, leaving some earth lodge designs out of compliance with building ordinances or local codes. Finally, earth lodges may be difficult to sell for families looking to relocate, which should be taken into consideration if lodges are to be privately owned.

Planning for earth berming, in-hill construction, and fully underground construction requires unique consideration and cost effective acquisition of the following:

- Sandy soils (50 to 75% sand) or soil that can be compressed
- Soil must be put through a sieve to reduce unwanted materials and structural problems
- Soil moisture must be below 10% to be compressed effectively
- Soil compaction is demanding, and will require machinery or resilient labor
- Framework materials, typically plywood
- Foundation material, ideally rubble trench or fully concrete
- Exposed exterior walls and roofing will require additional insulation and protection

Lodges ranging between 300 to 800 square feet can be built for between $3,000 to $10,000, or about $10 per square foot depending upon quality of building materials and the size of the building. This dollar amount assumes no hiring of outside labor, use of low tech solutions, and does not include cost of land, building permits, or utility connections. Lodges in this price range can be built sustainably and at low cost while still maintaining some or all of the following features:

- Gravel filled bags with insulating fill material on a rubble trench foundation
- Earth bag walls filled with soil or insulation
- Tamped earth, stone, or recycled brick flooring
- Various roofing options such as domes, green roofs, or water collecting metal roofing
- R-45 roof insulation
- Cabinets, wood stoves, storage, etc.
- Energy efficient doors, windows, and appliances
- Passive solar designs to heat interior or water
- Recycled materials for tiling, sinks, tubs, etc.

Earth lodges are ideal for integration with other sustainable technologies and practices. Because some or all land use is mitigated by burying the structure, more land is freed up for use toward other end goals such as water collection and storage, solar panel mounting, and gardening. The cool conditions and low sunlight inherent to earth lodge interiors make food storage easier to accommodate. Sewage and waste can be handled through most of the same mechanisms that any other lodging could provide. With the right materials and laborers at hand, any community could construct earth lodges to enhance their cultural expression and simultaneously incorporate sustainable practices and techniques.

Container Houses

Shipping containers or storage tanks offer an alternative of building houses in a fast, sustainable, and eco-friendly way. Both new and used shipping containers can be purchased easily at affordable prices compared to other conventional building materials, and they can be used for average-sized homes without many materials needed.

Advantages

Container houses do have some superior features in terms of building code. They are fast and easily constructed, just by laying containers side by side or stacking them to form multi-story homes, while they are still able to unify the surrounding neighborhood. Being manufactured under environmentally controlled conditions, shipping containers are standardized and reliable to handle heavy loads and extreme climate conditions. They are by far one of the safest shelters even during an earthquake, tornado, or hurricane. If properly insulated, they can become warm and cozy homes in winter and heat resistant dwellings in hot weather. Since containers are made for transport, they are also very compact and mobile.

Sizes and costs

The sizes of containers might vary, but these two standard sizes are the most popular:

- 20 feet long, 8 feet wide, and 8 feet tall
- 40 feet long, 8 feet wide, and 8 feet tall

Depending on the sizes and where containers are purchased, the costs can be different. A used 20-foot container in good conditions can have a price range of $1,400 to $2,800 while the price of a 40-foot one could be up to $3,500 to $4,500.

Building a house from shipping containers is very economical. For design and modifications, some contractors provide technical help to transform shipping containers into habitable houses, which usually costs $50-$150 per hour or around $10,000-$15,000 for a complete house. There are also some manufacturers who offer prefabricated shipping container houses which can be delivered to the location and ready for moving in. The price of a prefabricated house starts from $15,000 and up. Those who are more experienced with construction and prefer personal customization can manage to reduce the costs to less than $10,000 or even just $4,000 for a completely furnished home. In short, the total costs for a container house of 1,000 square feet could fall in $45,000-$85,000, not considering the cost of land and a foundation on which the container house will be built (see Appendix for details).

Utilities

Installing utilities in a container home is similar to a conventional home. The locations for plumbing is limited to two or three, while gas, water heater, even fireplace can run normally. Wiring could be under flooring or behind dry wall.

Some container houses can be designed with the roof top garden or solar heat reflection and potential rainwater harvest, making them ideal off-grid shelters.

Limitations

Shipping containers without being customized and combined might provide limited space for living due to their original sizes. Moreover, since being made from steel they can absorb and transmit the heat and cold easily. This will require proper insulation for temperature control and, accordingly, will increase the costs.

Availability and delivery costs are the other downsides of this dwelling style. Normally, it is easier if container houses are constructed in port areas where massive quantities of containers are available and affordable. Delivery costs in those areas could be cut down significantly.

The original purpose of shipping containers is not for human habitation; so they might pose health risks due to chemical elements or treatments used for modifications and preventing pest infestation. These problems should be carefully dealt with before beginning building with containers. Besides, building with new containers might ensure better quality of construction; however, it seems against the primary purpose of recycling the used ones.

Recommendations

Large variability in per square foot pricing restricts a more precise cost estimation which would help to have a better comparison between the three housing options. Thus, it is strongly advised that further study and revision should be done taking into account future prices and more specific requirements from Standing Rock.

With our current information, Straw bale houses are recommended because the materials are available at local sources and at affordable prices. These houses also instill and reflect simplicity, teamwork, and unity if the Standing Rock community decided to build these houses themselves, as these alternative homes reflect environmental and social awareness as well as independence. Such houses were first built in Nebraska in the 1880s, and now they are used in many states around the US. In fact, some of the houses build over 100 years ago still stand tall, such as the Haslow House in Nebraska.

Earth Lodges might also be a viable alternative, especially considering their low cost. Unfortunately, these low costs are only realized when many modern comforts are excluded, and inherently poor natural lighting conditions may be less appealing to those who have never lived in an earth lodge. We recommend that Standing Rock experiments with a few earth lodge test cases to see how the locals take to this form of alternative housing.

Container houses are another consideration due to their eco-friendliness and building advantages. This type of dwelling can be rapidly designed and implemented, and are well suited for completely off-grid housing solutions. Although the construction costs might higher among the three proposed housing options, the sturdiness against extreme weather conditions as well as their high durability and mobility could be worthy off-sets.

Sewage

Introduction

The purpose of the sewage waste management section is to promote the nexus of sustainability in the Mni Wiconi Eco-Village by focusing on the intersection of sewage waste management, energy generation, water conservation, and food production. This particular goal is achieved by recognizing the fact that conventional toilets and modern sewage infrastructure waste potential resources, but the use of compost toilets and anaerobic digesters have the ability to circumvent this wastefulness.

Based on feedback provided by representatives from the Standing Rock Sioux Tribe and Scott Medina from Blue Star Integrative Studio, the proposed Mni Wiconi Eco-Village will primarily rely on compost toilets for their sewage solution needs, an excellent option for new sources of human waste, because it immediately reduces water consumption at a relatively low cost per unit (Gough, 2017). In order to further promote this solution at the nexus of sustainability; however, additional management information is required. This is a topic that will be covered in a detailed discussion on available options and "best practices" in the management of composted fecal matter, including the conversion of this waste into Class-A fertilizer material.

According to regional experts, the camp will likely support 300-500 occupants on average—though, based on the shifting spotlight offered by the media, this number can increase to as many as 6,000 to 7,000 individuals to protest the Dakota Access Pipeline (Gough, 2017). In order to accommodate this potentially massive influx of people, the "best management practices" for compost toilets will largely rely on research provided by the National Parks Service, a federal agency that regularly contends with an unpredictable level of demand placed on their sewage management solutions (National Parks, 2015).

Of course, given the initial resources that this solution poses when it is considered as a replacement for existing sewage infrastructure, its viability for use in surrounding communities (e.g., Cannonball) diminishes. Therefore, this section will also discuss the use Anaerobic Digesters as a more appropriate solution for attaining the nexus of sustainability, specifically their ability to produce energy from bio-waste within well-established communities.

Options and Best Management Practices for Compost Toilets

As their name suggests, compost toilets rely on a carefully balanced environment that accelerates the decomposition process in order to seamlessly convert human waste into a compostable material. The composting environment itself—contained in a special chamber within, adjacent to, or beneath the toilet—requires a stable proportion of heat, oxygen, moisture, and organic matter to promote the biological processes of aerobic bacteria, the decomposers that break down the majority of the waste's pathogens and viruses. In conjunction with this removal of some of the waste's toxic nature, the digestion chamber also extracts liquids from the waste, ultimately reducing its volume by approximately 90% (EPA, 1999; National Parks, 2015). At the completion of this process, the remaining matter is odorless, safe, and relatively easy to dispose by depositing it in a permitted landfill or at a wastewater treatment facility (National Parks, 2015).

Initial Considerations

A commercial-grade, large capacity composting toilet can cost around $6,000, effectively servicing approximately twenty-eight people in a given day.[10] Based on the community's base-load projections and on the assumption that these compost toilets are the only sewage solution available, the client can expect to require a minimum of eleven toilets at a cost of approximately $66,000. Upkeep and installation costs are not included in this calculation, and this solution does not address the camp's need to support a large, unexpected influx of protesters (Ecoflo, 2017).

Regarding the installation of the toilet, the commercial-grade composters typically require the digestion chamber to be located beneath the toilet in a basement-like structure. Particularly for areas with cold winters, it is important that this basement is properly insulated and heated, otherwise the composting process will be ineffective. For reference, the National Forest Service recommends the use of a solar heat collector, thermoelectric generator, or a catalytic heater as the best options for supplying heat to the basement structure (n.d.). Depending on the manufacturer and the installation location, the cost of these heating solutions range from approximately $1,200 to $2,500 for a commercial grade unit, with the solar heat collector being the most expensive option (Dovetail, 2017; TEG, 2017).

Maintenance

With the exception of conventional toilets, composting human waste is a relatively easy sewage solution to maintain, though regular maintenance is absolutely necessary. Depending on the level of usage, digester tank size, ambient temperature, and climate; compost toilets will require the following: (1) the regular addition of wood chips into the digester tank, (2) the insertion and mixing of the fecal cone into the carbon source, (3) and the removal and disposal of the finished compost. In order to limit the unnecessary costs that are associated with employing maintenance personnel, the Natural Forest Service recommends locating the bin of wood shavings next to the toilet riser with an attached scoop (n.d.).

Sewage Treatment

Once the waste matter has been fully processed, its disposal is the next step in this sewage solution process. According to the National Forest Service, composted fecal matter must still be treated as domestic septage, meaning that local and federal regulations—in particular, Part 503 of Section 40 in the Code of Federal Regulations—require the treated material to be disposed in a permitted landfill.[11] In other words, although the process of composting waste is immediately beneficial to achieving water conservation, government regulations prohibit its application as a fertilizer without additional treatment.

To circumvent this restriction, the domestic sewage source may add an additional treatment measure, known as a "Process to Significantly Reduce Pathogens (PSRP)," which produces Class A Sludge, a regulatory term for sewage waste that requires no additional treatment and, therefore, may be applied as a plant fertilizer with no further regulatory restrictions.[12] To attain the status of Class A Sludge, the preparer of the biosolid matter must

[10] This estimate is based on a quote for the CM40, a commercial-grade composting toilet manufactured by EcoFlo Wastewater Management.

[11] Note: Additional local, tribal, or state regulations may apply.

[12] Only the attainment of a Class A sludge status is discussed in this section, because this form of treated sewage waste has fewer additional land application restrictions. Class B sludge is easier to attain; however,the following restrictions may apply: (1) edible food plants that do not touch the soil must not be harvested until 30 days after the biosolid application, (2) edible food plants that do touch the soil must not be harvested until 14 months after

meet maximum contaminant threshold requirements that control the spread of pathogens, reduce attraction vectors (e.g., disease-carrying organisms like flies and mosquitos), and limit the addition of heavy metals to the soil. The EPA offers three distinct and equally effective options to achieve compliance with Part 503: Exceptional Quality Biosolids (EQ), Pollutant Concentration Biosolids (PC), and Cumulative Pollutant Loading Rate (CPLR). It is worth noting however, that only the first option (Option EQ) is sufficient to eliminate any additional management restrictions from the federal government (EPA Biosolid Guide, 1994).[13]

As shown in the following four tables, a sewage source that is interested in applying their composted fecal matter to agriculture has a variety of options available to achieve this goal in a manner that protects human and environmental health. For Option EQ, the EPA's most effective treatment method, the additional treatment measures include (1) limiting heavy metals to the concentrations defined in Table 5.2, (2) using any of the alternatives in Table 5.3 (e.g., applying heat to the compost in order to kill existing pathogens), and (3) using any vector attraction reduction solution between Options 1 and 8. By following this process, the highest grade of Class A sludge is produced and may now be applied to gardens and fields with no additional land management restrictions (EPA Biosolid Guide, 1994).

Table 4. Land Application Compliance Options. Source: EPA, Table 2.2 Guide to Part 503

Option	**Heavy Metal Limits**	**Pathogen Requirements**	**Vector Attraction Requirements**
EQ	See Table 5	Any Class A Requirement in Table 6	Any of the Options 1 through 8 in Table 7
PC	See Table 5	Any Class A Requirement in Table 6	Either Option 9 or 10 in Table 7
CPLR	See Table 5	Any Class A Requirement in Table 6	Any of the Options 9 through 10 in Table 7

Table 5. Maximum Heavy Metal Threshold. Source: EPA, Table 1 Section 503.13

Pollutant	**Ceiling Concentration Limits (mg/kg)**
Arsenic	75
Cadmium	85
Chromium	3,000
Copper	4,300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7,500

application of the biosolid, (3) animals cannot graze on biosolid treated land until 30 days after application, and (4) land with high exposure to the public cannot be accessed for up to one year after biosolid application.

[13] Note: The sustainable sewage management section limits its discussion to only the most important land application regulations. For an in-depth review of federal requirements, please refer to the EPA's "Plain English Guide to Part 503 Biosolids Rule.

Table 6. Pathogen Reduction Options. Source: EPA, Guide to Part 503

Option	Explanation
Alternative 1: Thermally Treated Biosolids	Use a time-temperature regimen, as defined by a series of equations that consider the solid-liquid nature, particle size, and how those particles are exposed to the heat.
Alternative 2: High pH – High Temperature	(1) Elevate the pH to greater than 12 for 72 hours while maintaining a temperature above 52 degrees Celsius and then (2) Air dry at least 51% of solids after Step 1.
Alternative 3: Other Known Process	As a flexibility in federal regulations, other known processes are acceptable, provided the source can demonstrate a sufficient reduction in pathogens.
Alternative 4: Unknown Process	This alternative is similar to alternative 3, but it applies to treatment processes that are unknown or are less stringent that the other processes.
Alternative 5: Process to Further Reduce Pathogens (PFRP)	Specific additional requirements for composting, heat drying, heat treatment, thermophilic aerobic digestion, beta or gamma ray irradiation, and pasteurization
Alternative 6: Process Equivalent to PFRP	A list of equivalent processes is available on the EPA's website.[14]

Table 7. Vector Attraction Reduction Options. Source: EPA, Guide to Part 503

Alternatives (select 1)	Explanation
Option 1	Reduce the mass of volatile solids by a minimum of 38%
Option 2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit.
Option 3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit
Option 4	Meet a specific oxygen uptake rate for aerobically treated biosolids
Option 5	Use aerobic processes at greater than 40 degrees Celsius for 14 days or longer
Option 6	Add alkaline materials to raise the pH

[14] https://www.epa.gov/biosolids/examples-equivalent-processes-pfrp-and-psrp

Option 7	Reduce moisture content of biosolids that do not contain unstabilized solids from other than primary treatment to at least 75% solids
Option 8	Reduce moisture content of biosolids with unstabilized solids to at least 90%
Option 9	Inject biosolids beneath the soil surface within a specified period of time, depending on the level of pathogens treatment
Option 10	Incorporate biosolids applied to or placed on the land surface within specified time periods after application to or placement on the land surface

Compost Toilet BMPs Summary

Initial Considerations

- During cold months, use a solar heat collector, thermoelectric generator, or a catalytic heater to supply heat to the digestion chamber.
- The supply of heat ensures the aerobic bacteria survive and are able to fully process the compost

Maintenance

- Place the wood chip container (or other carbon source) and an appropriately sized scoop next to the toilet with instructions for users to add one scoop per use.
- Regularly mix the fecal cone with the wood chips.
- Remove composted material once the bin is near capacity, which should take approximately 18 months on average.

Sewage Treatment

- Following the initial conversion process, the compost must be disposed of in a permitted landfill or receive additional treatment.
- Additional treatment that produces Class A Sludge allows it to be applied as a fertilizer
- Regarding treatment options, Option EQ is the only sewage treatment solution that allows application of the biosolid directly to the land with no additional land management restrictions.
- Batch composters can be used to finish treating material from a compost toilet.
- When proper process and controls are used, a Class A sludge can be produced.

Anaerobic Digesters

Anaerobic digesters are an alternative to septic tanks with the added benefit of biogas and fertilizer as an output. The design of an anaerobic digester is essentially the same as the septic tank except the waste is contained in an airtight environment wherein methanogenic bacteria ultimately produce methane gas that is withdrawn for useful energy. Anaerobic digesters can be designed to be fed in batches or continuously fed. For continuous systems, there must be a constant feedstock influent to maintain the levels of methanogenic bacteria which produce what is known as biogas: a combination of gases including methane.

Feedstocks for anaerobic digesters include food wastes, human waste, and animal wastes. Animal wastes from farms in Sioux County may be transported to a central collection facility as an additional feedstock stream. Food wastes may also be collected from residences and/or restaurants, then transported to the anaerobic digester site. Addition of straw pellets, woodchips, or saw dust can be added to the digester to gain higher gas production from the bioreactor ("Biogas of Manure", 2013).

Composition of biogas

- ~50-75% methane (CH_4)
- ~25-50% Carbon Dioxide (CO_2)
- Varying quantities of H_2O and H_2S
- Trace amounts of NH_3, H_2, CO and N_2

Table 8. Feedstock Biogas Yields

Manure Type	Manure produced (Kg/animal/day)	Gas produced (l/kg waste)
Cattle	10	40
Buffalo	15	30
Pig	15	30
Chicken	2.25	70
Horse	16	130
Human	0.4	28

There are four phases of the anaerobic digestion process: Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis.

- **Hydrolysis** - non-soluble biopolymers converted to soluble organic compounds
- **Acidogenesis**- soluble organic compounds converted to volatile fatty acids (VFA) and CO_2.
- **Acetogenesis**- conversion of volatile fatty acids to acetate and H_2
- **Methanogenesis**- conversion of acetate and CO_2 plus H_2 to methane gas

Temperature, pH and alkalinity and toxicity are primary control factors for the environment of the digester. The pH should be as close to 7 as possible, but the digester can still operate if the mix inside is slightly acidic or slightly basic (pH=6.5-7.5). There are three temperature ranges for anaerobic fermentation: Psychrophilic, Mesophilic, and Thermophilic. The different temperature ranges have varying retention times. An anaerobic digester functions most efficiently in terms of biogas production in the thermophilic range (above 30° C.) The hydraulic retention time (HRT) of a reactor should be at least 10 days for hot climates and a minimum of 25 days (preferably 30) in temperate climes (Werner, 1989). Lower external temperatures result in longer retention times.

Table 9. AD Operating Temperatures and Retention Times

Digestion	Minimum	Optimum	Maximum	Retention Time
Psychrophilic	4 – 10 ° C	15 – 18 ° C	25 – 30 ° C	> 100 days
Mesophilic	10 – 20 ° C	28 – 33 ° C	35 – 45 ° C	30 – 60 days
Thermophilic	25 – 45 ° C	40 – 60 ° C	75 – 80 ° C	10 – 16 days

The methane gas produced from the anaerobic digester may be used in a combined heat and power (CHP) generator which can supply locally sourced electricity to the community or provide a revenue stream from electricity sold to the grid. Before combustion, the gas produced from the bioreactor must be treated to remove contaminants and prevent wear and tear on the generator. If smaller scale anaerobic digesters are being considered for a cluster of homes, the gas may be piped into homes for cooking usage. The effluent from the anaerobic digester may be used as liquid fertilizer. Some education or training may be required to teach individuals in the community about the use of the effluent as a fertilizer (some might not be accustomed to only using solid fertilizer).

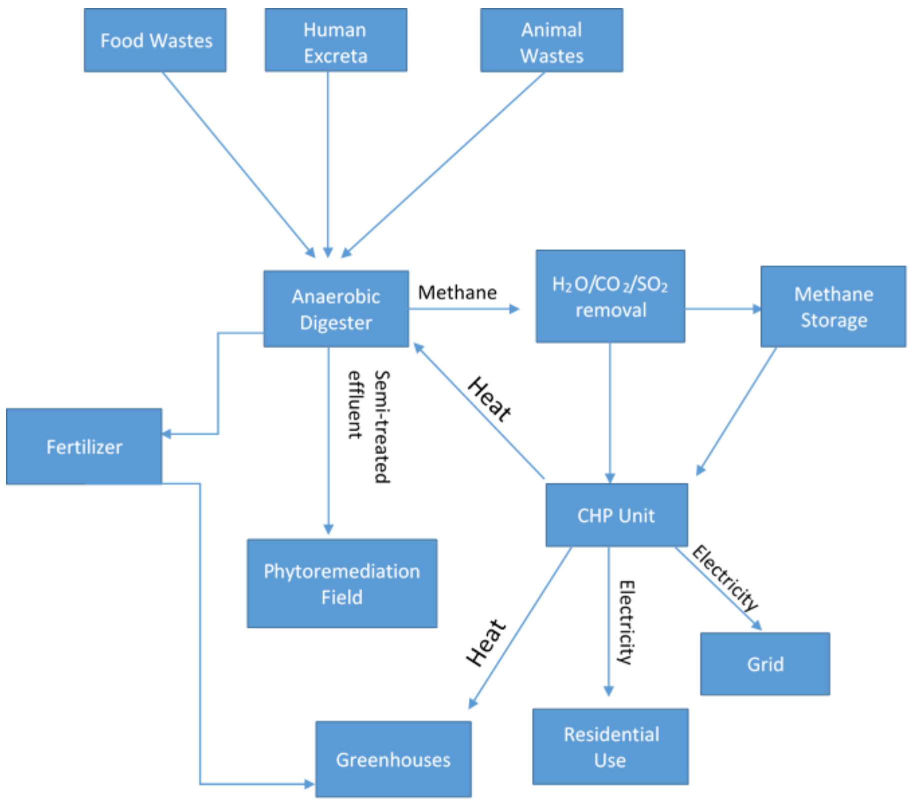


Figure 7. Concept diagram for anaerobic digester system

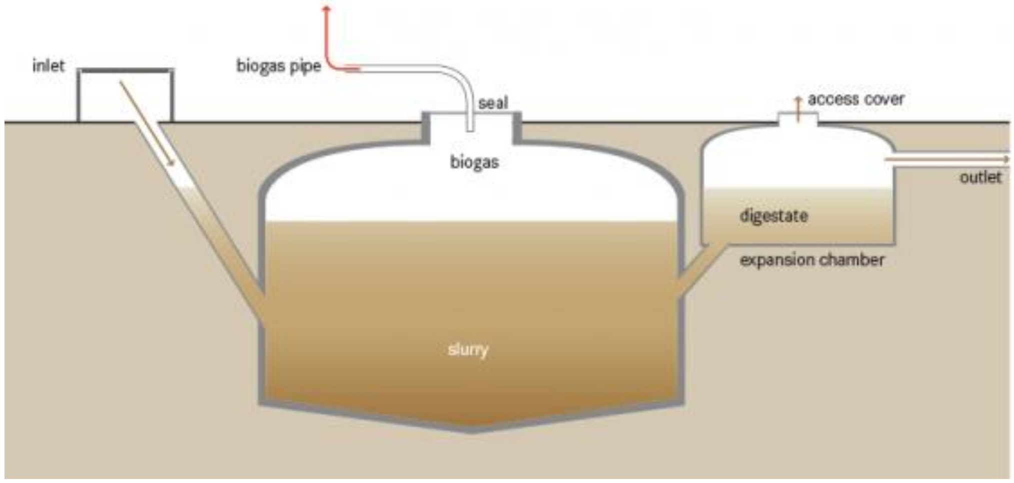


Figure 8. Schematic of an anaerobic digester (Tilley et al. 2014)

Biogas reactor designs vary by location and application. Given the colder temperatures in North Dakota, the anaerobic digester unit would likely need to be buried to better insulate the digester. For a larger scale application involving feedstock inputs of local animal manure, a heating element (possibly the CHP unit itself) could be used to increase the temperature of the digester to enhance biogas production. A buried fixed dome reactor design could be utilized for smaller scale applications. For this type of AD application, the methane would likely be used as an energy source for cooking in the home, but a system could theoretically be designed which stores the gas in tanks during non-winter months to be withdrawn for heating purposes during the winter. Utilization of methane produced from an AD would reduce the reliance on conventional fossil fuels to meet energy demand. The use of AD digestate as locally sourced fertilizer will make agriculture more sustainable as it will reduce the use of commercial fertilizers.

Septic Systems

Septic systems are commonly used options for decentralized, long-term, effective treatment of household wastewater. The components of a septic system include pipe from the home, the septic tank, and a drain field. A septic tank is a buried, watertight container used to hold wastewater long enough to allow solids to settle, forming sludge. When sludge settles to the bottom of the tank, oil and grease accumulate on the top layer, forming scum (EPA Septic Systems). If improperly maintained, septic system components must be replaced at a high cost, up to thousands of dollars. The costs of an improper septic system management are not only monetary as groundwater (a potential source of drinking water) contamination can result from a malfunctioning system.

The EPA lists four things homeowners can do to maintain septic systems:

1. Regularly inspect the system and pump the tank as necessary
2. Use water efficiently
3. Don't dispose of household hazardous wastes in sinks or toilets
4. Provide care and attention to the drainfield

Inspection of the septic system includes the following:

- Locating the system
- Uncovering access holes
- Flushing toilets
- Checking for signs of back up
- Measuring scum and sludge layers
- Identifying any leaks
- Pumping tank if necessary

Below are best-practices for maintaining the drainfield of a septic system:

- Plant only grass over and near septic systems. Roots from nearby trees or shrubs might clog and/or damage the drainfield.
- Refrain from driving or parking vehicles on any part of a septic system. Doing so can compact the soil in the drainfield or damage the pipes, tank, or other septic system components.
- Keep roof drains, basement sump pump drains, and other rainwater or surface water drainage systems away from the drainfield. Flooding the drainfield with excessive water slows down or stops treatment processes and can cause plumbing fixtures to back up.

Conclusions

The adoption of the best practices and alternative methods of sewage treatment described would ensure sustainability of sewage treatment in communities on the Standing Rock Reservation. The adoption of human waste treatment methods like composting toilets, anaerobic digesters, and septic tanks are effective decentralized methods to treating sewage. The nexus of sustainability can be achieved with the suggested treatment methods in the following ways:

- Septic tank best practices will protect soil and water from contamination
- Composting toilets will reduce water consumption
- The compost produced from composting toilets can be used to grow plants
- Use of anaerobic digesters will produce energy from waste, reducing reliance on fossil fuels
- The digestate from an anaerobic digester can be used for sustainable food production

Solid Waste

Introduction

Sustainable solid waste management in a community is achieved when the community is able to meet various requirements. Such requirements include development of a clear organizational strategy, adherence to applicable waste management laws (like the federal 1980 Resource Conservation and Recovery Act), and promotion of sufficient community buy-in. These goals can be challenging to meet without access to suitable disposal facilities, adequate waste transportation systems, and sufficient funding. Here, we consolidate our findings on the resources and challenges that are specific to the Standing Rock Sioux Tribe's need for sustainable solid waste management. We then identify potential paths toward sustainable solid waste management, taking into consideration the identified challenges. This section culminates with our recommendations of the efforts that we believe will provide the best balance of impact-for-investment.

Existing Infrastructure

To correctly assess the economics of the waste management practices in place, we considered access to landfills and estimated distance of landfills within a 130-mile radius of Cannon Ball and Fort Yates communities. Landfills nearest Cannon Ball are Bismarck City Landfill (located about 35.4 miles from the community), Mandan Landfill (36.6 miles), Wishek Landfill (46.2 miles) and Waste management (111 miles).

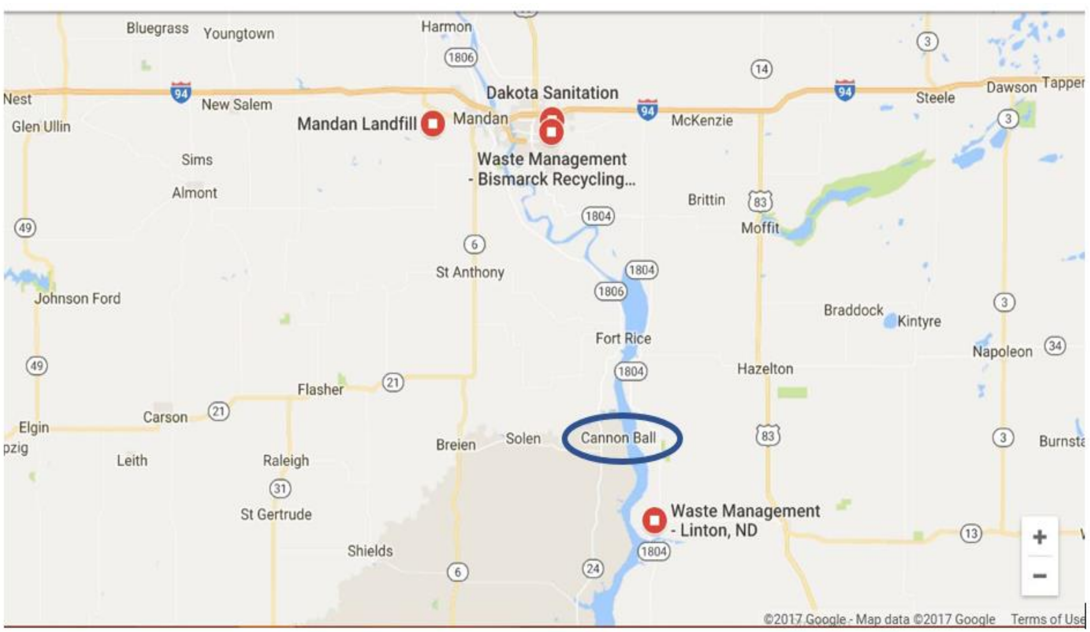


Figure 9. Landfills near Cannon Ball

Nearest landfills to Fort Yates are Walworth county landfill (2 below, 53.8 miles away); Mandan landfill (5) 67.9miles, Bismarck city landfill (3) 68.4 miles, and Jahner Landfill (4) 126.3miles.

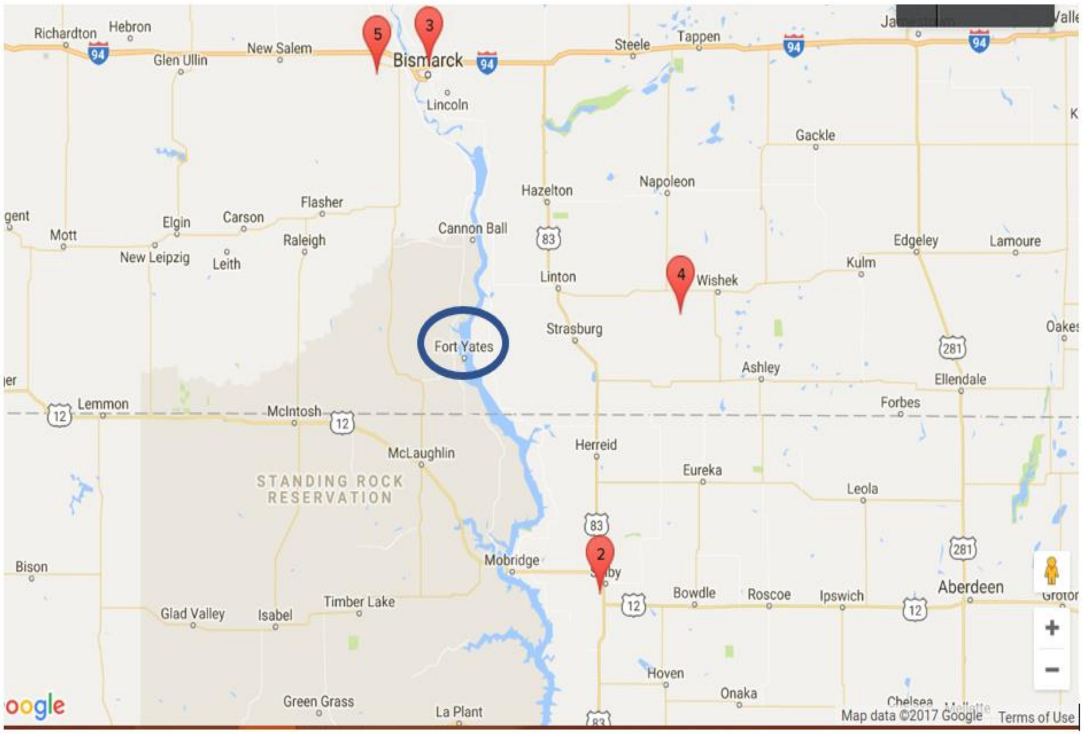


Figure 10. Landfills near Fort Yates

No DAPL Protest Camps

This section is for the benefit of the next capstone and readers outside of the Standing Rock community for future use.

In August of 2016, Standing Rock attracted global attention through protests of the North Dakota Pipeline project – a pipeline that was re-routed just North of the Standing Rock Reservation, set to cross underneath the Missouri River, the drinking water source of several communities and important spiritual landmark for the Sioux Tribe. Standing Rock Sioux Tribal members have been protesting this development since just after it was approved by North Dakota in January of 2016 – LaDonna Brave Bull Allard founded the first protest camp in April of 2016, eventually to be called Sacred Stone. Large crowds of supporters were drawn to Standing Rock that summer, eventually totaling more than 10,000 people.

In December of 2016, after almost a year of conflict and political swings, the Army Corps of Engineers announced intent to launch a more intensive and lengthy environmental impact review of the pipeline project. This announcement, and the impending harsh winter living conditions in the northern plain, prompted many protesters to evacuate in the coming months. Protest camp leaders, with the help of volunteers and donations from across the country, led cleanup efforts until all of the camps were eventually forcefully evacuated and the Amy Corps of Engineers took over the cleanup process.

One of the biggest and most recent developments to originate from the reservations is the fallout of the Oceti Sakowin protest camp that was based in Cannon Ball, North Dakota. This camp was home to an estimated 4,000 people (Northcott, C. 2016, December 2) that included several families and numerous individuals. The almost year-long protest ended when the campers received an eviction notice from the Army Corps of Engineers. While the protestors emptied the site, they left behind some of their belongings that included tents, teepees, sleeping bags, blankets, canned goods and garbage (Szczepanski, M. 2017, February 14).

All of the things that were left by the protestors posed a threat to the same environment they were trying to save and protestors were accused of degrading the site (Bernish, C. 2017, February 8). To avoid any damage from the leftover waste, the Standing Rock Environmental Protection Agency, the Standing Rock Sioux Tribe, Dakota Sanitation & Roll-Off Service Inc., Thunder Valley Community Development Corp., and other local organizations joined hands to clean up the site in a timely manner. The trash was collected and hauled to a landfill in Bismarck, North Dakota (Szczepanski, M. 2017, February 14).

All of this impacted the protest and the cause of the participants negatively, which highlighted the attitude towards waste management. This incident made many news reports, and the genuineness of the protest was questioned. It is estimated that over $1 million has been spent so far to haul 24,000 tons of trash from the site (Adelman, B. 2017, March 01).

Since approximately 4,000 people were evicted, it is likely that some of them will move to the existing communities or build new ones. The suggestions for best practices for solid waste management may not be well received if the people's attitude have not changed. This may be the biggest challenge the community will face.

Moving forward, we have to determine how the protestors' stint will affect the application of the suggestions made by us. The protestors put a lot of time and resources into cleaning up the camps before the Army Corps of Engineers took over the camp and the cleanup efforts. One of the main reasons the protestors were unable to finish the cleanup was because the waste was covered in snow and they did not have the means to clear the snow. This could be a challenge to the people of the communities if they intend to take the right efforts but don’t have the means to deal with climate consequences and therefore, hinder the application of the recommended methods.

Figure 11. Challenges to managing tribal solid waste, as summarized by Hartnett, M. and Rohlfs, B. (2012)

With ever increasing population and the number of operations carried out in the last two decades, the need for solid waste management has only gone up. Solid waste management is a difficult process that needs a lot of attention to detail from both, government and the civilians, to ensure the success of the efforts taken. Challenges faced by the communities of the Standing Rock Tribe are minimal, but colossal. Need for a solid waste strategy and lack of interest are the main challenges that we found in reports that need to be tackled head-on. For the purposes to better understand the current scenario on-site, we reviewed a couple of documents that pertained directly to the Standing Rock Reservation. They are "The Standing Rock Sioux Tribe Comprehensive Economic Development Strategy (CEDS)" and "Solid and Hazardous Waste Management Code". The former includes various development strategies planned by the community in order to receive funding from the U.S. Department of Commerce Economic Development Authority's (EDA) Public Works or Economic Adjustment Assistance Programs and the latter includes all the codes and regulations relating to the collection, transportation and disposal of the solid waste generated on the premises.

A SWOT analysis has been carried out in the CEDS documents which reflects on the strengths, weaknesses, opportunities and threats the community faces. The need for a 'solid waste disposal strategy' is mentioned as one of the weaknesses. One of the other weaknesses that was mentioned include lack of insufficient funding for road maintenance. This could hinder the possibility of developing a good solid waste disposal strategy as transportation will play a vital role in it. The documented also informed us about the current disposal state at the reservation. The regulations and codes are causing the landfills to shut down resulting in either scattered litter or large piles of trash. This has resulted in two things; the prices to operate landfills to go up and loss of economic development as businesses back out due to higher costs of waste disposal. However, this presents the community with an opportunity to invest in recycling and reusing techniques. The other major aspect we found that could contribute to the lack of proper disposal strategy was the presence of really stringent rules for storage and transportation of waste generated. This includes very specific instructions that the inhabitants and the businesses have to adhere to. With landfill shutting down and high cost of transportation, the laws only make it difficult for the authorities to put in place a sound strategy to deal with the solid waste problem.

As a result of high disposal cost and limited opportunity for alternative waste disposal options like recycling, several Standing Rock communities are home to open dumps – waste disposal sites that fail to meet federal criteria. Open dumping threatens human and environmental health – a lack of management and treatment of certain wastes may allow hazardous substances to flow into groundwater and pollute drinking sources and soils of neighboring or downstream communities. Furthermore, closing or such sites are costly and require technical expertise to comply with federal regulations.

The Standing Rock Tribe, in collaboration with the Indian Health Service and the U.S. EPA, has inserted effort into closing sites and discouraging illegal dumping on open land (see Figure 3, below). However, of 2012, at least ten open dump sites were listed by IHS Division of Sanitation Facilities Construction as "Open dump – surface," as opposed to "Open dump – cleaned up," meaning that even if these open dumps were inactive, they still were not cleaned and posed a spectrum of health threats to surrounding communities. For example, Cannonball dump, although inactive, was considered a "high" threat to human health and contained Municipal Solid Waste as well as "Special Waste."

Figure 12. Evidence of collaboration between the Standing Rock Tribe and U.S. EPA in enforcing and discouraging illegal waste disposal presented by Hartnett, M. and Rohlfs, B. (2012)

Findings

Applicable Laws

Solid waste management in Indian Country can fall under several jurisdictions, depending on the characterization of the land and preexisting legal arrangements between individual tribes, states, and federal government. Primarily, solid waste is regulated by Tribes, states, or a partnership between the two, depending on the status of the land where the waste disposal occurs (i.e., tribal lands, land held in a trust, "fee lands," etc.). The strict exception is hazardous waste, which is regulated by the US EPA according to RCRA Subtitle C.

Subtitle D of RCRA, which defines solid waste criteria and regulations, define tribes as municipalities. This removes tribes from the need to submit solid waste permitting plans to the EPA for review. (Hartnett & Rohlfs, 2012) Instead, tribes are accountable for developing and implementing solid waste management plans. (*Blue Legs*, 1987) Tribes are also able to construct and operate landfills, as long as they comply with relevant federal criteria (40 CFR Parts 257-258).

Given the low median household income for the North Dakota Standing Rock Sioux ($29,858 in 2009 dollars, up from $21,625 in 2000; U.S. Census Data), disposing of household waste in open dumps is a common and problematic practice on the reservation, as it is for other Indian Nations. (Hartnett & Rohlfs, 2012) In 1994, Congress acknowledged the environmental and public health dangers inherent to lands surrounding open dumps with the "Indian Lands Clean Up of Open Dumps Act". This act established the following priorities: to locate open dumps on Indian lands, to evaluate the hazards to human health and the environment by these dumps, and to provide technical and financial resources to Indian tribes to close these dumps according to relevant Federal regulations and laws (or Indian tribal equivalents—whichever are more stringent).

Valuable Documents

Four documents that were published by sources internal or external to the Standing Rock Sioux COUP were identified as informative resources for discerning the context and scope of the goals for the Solid Waste working group**.** These documents are summarized below:

- Tribal Document: The Standing Rock Sioux Tribe's Solid and Hazardous Waste Management Code: TITLE XXVI (Public Post Jan 2016). Accessed 26 January 2017 from www.standingrock.org/linkgen/?media_id=1197
    - This document summarizes codified solid and hazardous waste management rules that are recognized by the Tribe, in observance of its members' right to a clean environment; and that are to be promulgated by the Director of the SRST Department of Environmental Regulation/EPA with oversight from the Environmental Quality Commission.
    - Chapters of interest include:
        - Chapter 5: Tribal Integrated Solid Waste Management Plan (pp. 38-41)
        - Chapter 6: Recycling (pp. 41-42)
        - Chapter 13: Household Waste Storage, Collection and Control (pp. 83-87)
- Federal Document: Developing a Tribal Integrated Waste Management Plan (IWMP). (EPA) https://www.epa.gov/tribal-lands/developing-tribal-integrated-waste-management-plans
    - U.S. EPA provides a flexible framework for Tribal leaders to develop an Integrated Waste Management Plan. To do this systematically, authors recommend determining and clearly defining the area of service, characterizing and assessing community waste, determining and describing current waste management practices and defining future desired waste management practices (clear goals). The community then must identify challenges in waste management, investigate options from developing a recycling program to building a transfer station or landfill, performing a cost/benefit analysis of options and selecting an option. Finally, a community must write and implement their IWMP, continuing monitoring and evaluation into the future in order to ensure that practices are effective, safe, and are improved if necessary.
        - Important sections of this 2013 U.S. EPA document are available in Appendix 1, Figures 1, 2, 3, 4
        - This process, of course, requires time and resources that not every community or Tribe may have, especially rural communities. EPA Region 8 does not advertise funding programs or collaboration with Tribal communities. This identifies a gap in collaboration that may be fulfilled through cooperation between EPA and Tribal communities, best exemplified by EPA Region 9 (Pacific Southwest) communities and discussed later in this section.
- Federal Document: Tribal Solid Waste Program Costing Tool. (EPA) https://www.epa.gov/statelocalclimate/tribal-solid-waste-program-costing-tool
    - Important sections of this 2009 U.S. EPA resource are available in Appendix 1, Figures 5, 6, 7, 8

- Presentation Slides: Solid Waste Mgt. in Indian Country. Hartnett, M. and Rohlfs, B. (2012) https://www.ihs.gov/EHSCT/.../sfc.../IHS_SW_in_Indian_Country_July_2012V5.pdf

Water

Introduction

This chapter presents the best practices for sustainable water management on tribal lands. The four primary methods addressed include water conservation and efficiency, graywater, wells, and rain barrels. Water conservation methods and efficient appliances are ways to maximize the use of available water and minimize waste. Installing rain barrels and reusing graywater are means of capturing and utilizing available water to be used for non-potable purposes. Drilling wells promote water independence, which is particularly useful in rural areas. Although not all methods of sustainable water management are addressed, this chapter identifies and explains some of the most effective methods to manage water.

Water Conservation and Efficiency

Water conservation involves the efficient use of water and avoiding its waste. Implementing water conservation methods will maximize this vital resource while saving energy associated with its transport, heat, and/or treatment. Simple ways of conserving water can reduce expenses for water, while investments in more water-efficient appliances and fixtures can also save money over time. Water conservation is especially essential for a semi-arid climate like that present at the Standing Rock Sioux Reservation.

Conservation and Efficiency Best Practices

There are many ways to conserve home water use and use water more efficiently. Listed below are some of the most simple and effective means of doing so. The description of each practice includes the associated installation cost, water savings, financial savings, and the practice's level of difficulty.

Repair leaks

Leaks can contribute to large amounts of household water waste. For the average household, a leak could account for 10,000 gallons of wasted water per year. In fact, 10 percent of houses have leaks that waste 90 gallons of water per day (EPA, 2017). Having a water bill with more than 12,000 gallons for a month may be a sign of leak. There are multiple sources of water leaks, such as faucets, toilet flappers, showerheads, and more. Some of these leaks can be simple fixes, including replacing worn faucet washers and gaskets, replacing worn toilet flappers, and securing connections between fixtures and pipe stems. If these more simple measures do not stop the leaks, then it might be time to replace the fixtures. These repairs can be completed by someone with basic plumbing knowledge, which would only require the cost of the supplies. However, more serious leaks and replacing of fixtures may require a licensed plumber, which could cost up to several hundred dollars. Depending on the scale of the leak and repair costs, the costs could easily be recovered in a relatively short amount of time.

Encourage smart water conservation practices

Significant amounts of water use can be reduced just by changing personal behavior. Here are some simple ways for individuals to reduce household water use:

- Take shorter showers
- Turn off faucet while brushing teeth
- Run only a full dishwasher

- Wash only full loads in the washing machine
- Plant native and drought-tolerant plants for landscaping

Install low-flush or dual-flush toilets

Most older toilets use about 3.5 gallons per flush (gpf), while the newer standard is 1.6 gpf. Low-flush toilets go beyond this standard and use about 1.28 gpf (EPA, 2017). Furthermore, there are low-flush, dual-flush toilets that offer two options: a full flush and a reduced flush. Low-flush toilets tend to vary between $100 and $350. While a homeowner may be able to install a toilet themselves, getting a professional to install one could cost between $150 and $400. Installing a low-flush toilet can reduce associated water used by 20 to 60 percent, depending on the original toilet. This can amount to annual water conservation of 13,000 gallons for a family of 4, which corresponds with financial savings of $110 annually and $2,200 over the appliance's lifetime. While this conservation method involves a higher initial cost, this expense can still be recovered after a few years.

Install faucet aerators

Kitchen sinks generally require 1.0-1.5 gallons per minute (gpm), while bathroom faucets require about 0.5-1.0 gpm. Because standard faucets are 2.2 gpm, a faucet aerator can represent a 30 percent reduction in water use from faucets (Moloney, 2014). The price of faucet aerators generally range from $4-$6 and can be simple enough for homeowner installation. If a bathroom faucet is used 30 minutes per day, adding an aerator to a faucet that reduced it from 2.2 gpm to 1.0 gpm will lead to an annual savings of $26.40. If a kitchen faucet is used 30 minutes per day, adding an aerator to a faucet that reduces its flow from 2.2 gpm to 1.5 gpm amounts to an annual savings of $15.36. With an average cost of $5 per aerator, the investment is quickly recovered.

Install low-flow shower heads

Low-flow shower heads generally use 2.0 gpm or less, versus 2.5 gpm for a standard shower head at maximum flow rate. The price of low-flow shower heads can range from $10 to $50 and may be simple enough to install by the homeowner. For a household of four people, switching from a shower head with 2.5 gpm to a low-flow with 2.0 gpm can represent an annual savings of $100 and 7,300 gallons (Waterpik, 2017). Depending on household water use, the cost of a low-flow shower head can easily be recovered within a year.

Figure 13. Look for the EPA's WaterSense label to identify water-efficient products.

Graywater Reuse

Graywater is relatively clean wastewater generated from households and office buildings. Wastewater from toilets and washing diapers, which does contain fecal contamination, is known as blackwater. The most common sources of graywater include bathtubs, showers, sinks, and washing machines. While graywater may contain soap, dirt, hair, and household products, it is generally clean enough to water plants, making it a sustainable, on-site water management practice. Graywater can be a reliable source of water for landscaping and fruit trees, especially in water-stressed environments. Graywater use reduces potable water use, decreases waste bills, limits demand on septic systems, and reduces energy use and financial costs at wastewater treatment facilities. States and cities may have their own laws regulating how graywater may be used (Greywater Action, n.d.).

Best Management Practices for Graywater Systems

The following lists includes general best management practices that should be applied to all graywater systems (San Francisco Public Utilities Commission, 2012). These practices will ensure that the system works properly and is not detrimental to human or environmental health.

- Do not store graywater more than 24 hours
- Minimize contact with graywater
- Filter graywater and do not allow it to pool or runoff
- Install a diverter valve to allow for switching between graywater system and septic or sewer system
- Use plant-friendly soaps and cleaning products; avoid those containing salts, boron, or chlorine bleach
- Implement a simple system with limited maintenance needs
- Match the amount of graywater your plants receive with their irrigation needs
- Do not surface-irrigate plants that produce food, except for fruit and nut trees

Graywater System Designs

There are multiple system designs to reuse graywater. Although some are pre-manufactured or consist of more elaborate, pumped systems, others are simple, relatively inexpensive, and work just as well. Three common graywater systems are described below.

Laundry Drum

The laundry drum system is the most simple and least costly of the graywater reuse designs. This system works by connecting a "drum" or large barrel to the washing machine and setting it up outside of the residence. The drum collects and temporarily stores graywater that is pumped out by the washing machine. At the bottom of the drum is a hose that can moved around the yard to irrigate plants. While this is the easiest system to install, it does require repeated manual labor involved with transporting the hose to distribute the graywater evenly and avoid pooling or over-watering. Moreover, above-surface use of graywater is not preferable given potential contamination risks. However, this system is beneficial in situations where the distance between the residence and the irrigation area is large (Greywater Action, n.d.).

Laundry-to-Landscape

Similar to the laundry drum system, the laundry-to-landscape system also collects water from the washing machine by using the machine’s internal pump to retrieve the water. This system involves installing a diverter valve on the washing machine and attaching a hose, and differs in that it involves burying irrigation line to specific plants and digging mulch basins around the plants (see Figure 14). The mulch basins are useful to avoid clogging of the lines. The cost to install a laundry-to-landscape system could cost a few hundred dollars if installed by the homeowner or up to $1000-$2000 if installed by a professional (San Francisco Public Utilities Commission, 2012).

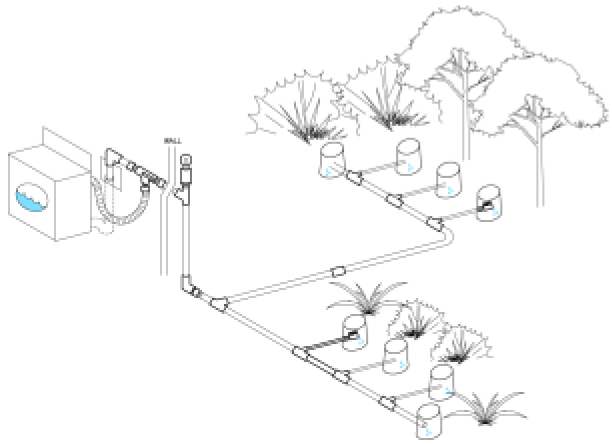


Figure 14. Laundry-to-Landscape system (Greywater Action, n.d.)

Branched Drain

This system involves modifying the household plumbing by extending pipes from sink and shower drains and branching them out below ground to reach different plants. Branched drains are typically used with drains that do not have an internal pump (like the washing machine, and thus rely on gravity for the graywater to flow. Therefore, this system works best when the area to irrigate is downslope from the graywater source. The graywater empties into mulch basins around nearby plants for irrigation (San Francisco Public Utilities Commission, 2012).

Wells

In order to increase self-reliance, this group recommends that members of the Standing Rock Tribe invest in residential wells on each property. The placement of wells, as opposed to connectivity to municipal water systems, will first allow each household to hold sovereignty over their own water source, and secondly, allow for a decrease in associated monthly expenses. Of the wells available for home installation, three types of systems meet the aforementioned criteria: drilled, drive-point and bored. These wells are the most common among residential systems and each are designed to work in different instances, with little variation in productivity of potable water. As many residential wells only require 100-800 feet of depth, these systems meet these requirements[15]. (*Table 10*)

Table 10. A summary and comparison of the identified well-drilling methods

Type of Well	Method	Explanation	Pros	Cons	Depth
Drilled	Cable Tool[1]	Uses a steel cable to raise and drop a heavy chisel-shaped bit, which breaks up sediment and rock into small pieces called cuttings. The cuttings are removed from the hole with a bailer — a hollow tube or pipe with a valve on the bottom. Steel well casing, is pounded into the ground as the hole is deepened.	•Less costly than Rotary Drilling •Suitable for most geologic conditions •Use of minimal manpower	•Difficult drill deep due to lightweight design	300-500ft
	Rotary[2]	Uses a rotating bit on the end of a hollow drill rod. Water and a special kind of clay slurry (called drilling mud) or foam are forced down the inside of the drill rod and out of openings in the bit as it rotates. The drilling mud or foam carries the cuttings, which consist of ground up rock and sediment, up and out of the space between the drill rod and the drill hole. Well casing is then lowered into the hole	•Used to penetrate medium-hard bedrock •Not affected by short-term droughts	•Five times more costly than Cable Tool drilling	100-1000ft
Drive-Point	Hammer[3]	Constructed using a pointed screen on the end of a series of tightly coupled lengths of steel pipe. The well casing pipe, which is usually 1¼ inches in diameter, is driven into the ground with a heavy hammer or well driver until the point is below the water table.	•Easily constructed in permeable soils •Best for high water tables	•High risk of contamination from land-use activities	5-100ft
Bored	Auger[4]	Constructed using an earth auger, which bores a hole into the earth. The bore hole is then lined — or cased — with masonry, concrete curbing, or casing	•Less costly due to low depth	•Difficult to penetrate many rocks or solid surfaces •More susceptible to changes in water level	30-100ft

1. Well Construction Example. (n.d.). Retrieved April 6, 2017, from http://www.alexanderhealth.org/docs/enviroHealth/WellConstructionExamples.pdf
2. Well Drilling Methods.(n.d.). Retrieved April 6, 2017, from http://www.michigan.gov/documents/deq/deq-wb-dwehs-gwwfwim-section5_183030_7.pdf
3. Driven-Point (Sand-Point) Wells. (n.d.). Retrieved April 6, 2017, from http://dnr.wi.gov/files/PDF/pubs/DG/DG0022.pdf
4. Bored and Drilled Wells in Piedmont North Carolina. (n.d.). Retrieved April 6, 2017, from http://www.alexanderhealth.org/docs/enviroHealth/WellConstructionExamples.pdf

Drilled wells, typically the most common type, are installed via two construction methods: cable tool or rotary. With the cable tool method, a steel cable is used to raise and drop a heavy chisel-shaped bit, which breaks up sediment and rock into small pieces called cuttings. The cuttings are removed from the hole with a bailer (a hollow tube or pipe with a valve on the bottom). Steel well casing is pounded into the ground as the hole is deepened.[16] Due to the tools used to drill and support the well, this method is far less expensive and can be operated with less manpower than the rotary method (described below). Another benefit of the cable tool method is that it can be used in almost any soil condition, whether it be hard rock, clay, or gravel ground.

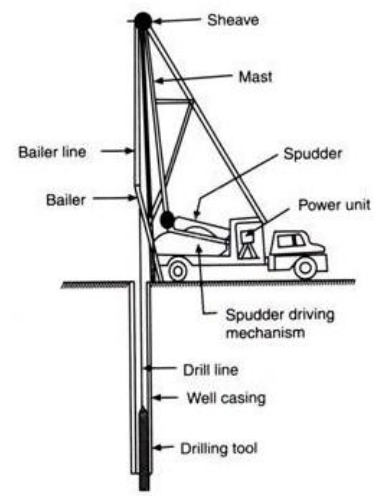


Fig. 18.6. Truck mounted cable tool machinery

Figure 15. Cable Tool Setup (Blue Nose Well Drilling)

[15] Determining the Depth of a Well. (2014, June). Retrieved April 4, 2016, from https://www.watersystemscouncil.org/download/wellcare_information_sheets/basic_well_information_sheets/DEPTH%20OF%20WELL_FINAL.pdf

[16] Well Construction Example. (n.d.). Retrieved April 6, 2017, from http://www.alexanderhealth.org/docs/enviroHealth/WellConstructionExamples.pdf

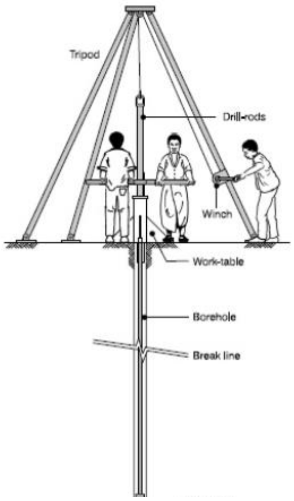


Figure 16. Rotary Drill Setup. (American Groundwater Trust)

However, due to the lightweight design of the tools, a potential tradeoff to this method is difficulty with digging deeply at a reduced cost.

The rotary method of digging wells utilizes a rotating bit on the end of a hollow drill rod. Water and a special kind of clay slurry (called "drilling mud") or foam are forced down the inside of the drill rod and out of openings in the bit as it rotates. The drilling mud or foam carries the cuttings, which consist of ground up rock and sediment, up and out of the space between the drill rod and the drill hole. The well casing is then lowered into the hole[17]. This method, as opposed to the cable tool method, is primarily used for deep wells where the groundwater source is farther from the surface, and utilizes tools designed to penetrate medium to hard bedrock. In addition, due to the deep extension this type of well, it is not typically affected by short-term droughts. It is roughly five times more costly than cable tool drilling primarily due to the heavier, more durable tools that are required.

The drive-point type of well makes use of the hammer construction method. This method involves using a pointed screen on the end of a series of tightly coupled lengths of steel pipe. The well casing pipe (usually 1¼ inches in diameter) is driven into the ground with a heavy hammer or well driver until the point is below the water table[18]. Due to the relative simplicity of this method, it is generally less expensive and is suited to high water tables that are accessed through highly permeable soil types like sand or gravel. However, given this shallow, permeable cover over the water table, there is a high risk of contamination to the water source and associated wells from land-use activities (e.g., farming or dumping).

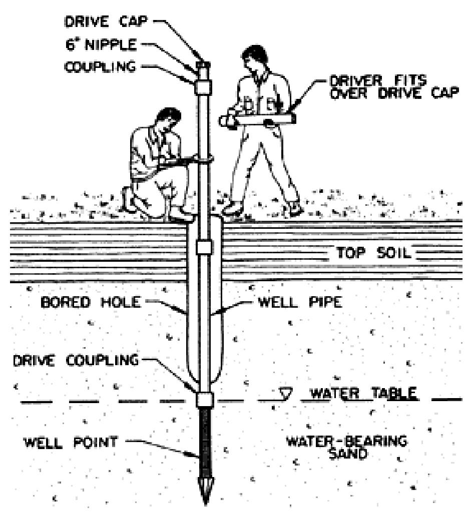


Figure 17. Drive-Point Well Setup. (Roger E. Machmeier)

The final well type is constructed with an auger and is called a bored well. The process is straightforward: an earth auger bores a hole into the earth to a high water table. The bore hole is then lined — or cased — with masonry, concrete curbing, or casing[19]. Similar to the drive-point wells, the simplicity of the design and the shallow drill depth make bored wells a less expensive option. Once again, however, due to the shallowness of the well, it is susceptible to changes in water level and quality. Also, the auger is not ideal for penetrating numerous types of rocks and solid surfaces, making it a poor choice for deeper well construction.

[17] http://www.michigan.gov/documents/deq/deq-wb-dwehs-gwwfwim-section5_183030_7.pdf
[18] http://dnr.wi.gov/files/PDF/pubs/DG/DG0022.pdf
[19] http://www.alexanderhealth.org/docs/enviroHealth/WellConstructionExamples.pdf

Due to the possibility of contamination from other well designs, the recommendation of this working group is that wells should be constructed using a *drilled well* method, with a preference toward the *cable tool* method. The ground beneath the Standing Rock Reservation is a mixture of clay and sandy soil, which should be well within the limits of the cable tool method. The depth of the well is dependent on water table location, among other factors; therefore, qualified installers should be consulted prior to deciding on well depths.

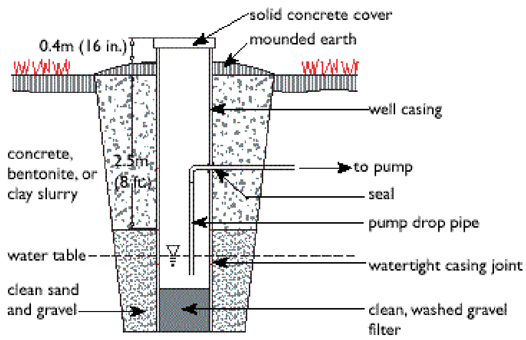


Figure 18. Bored Well Well Setup. (Royal LePage)

Rain Barrels

Another option for increasing water independence is rain barrels, which can supplement non-potable water needs. For example, rain barrels can easily be adapted to provide water for small-scale crops in installations such as greenhouses. As the Eco-Village plans to use greenhouses for food production, the rain barrels detailed here will be scaled for that application. The exact details of the greenhouse have not been released at the time of this report, so all dimensions and recommendations provided will be in general terms.

According to the National Weather Service weather station at Bismarck, ND, which provides measurements that are most easily generalized to the Eco-Village given its close proximity, the average annual precipitation is 17.82 inches with 14.83 inches of that falling during the growing season. For many plants during spring and autumn growing seasons, 0.5 inches of rain are required per week. During the summer peak growth period, plants require roughly double that amount—at a minimum, one inch of water per week across the surface area of the growing soil.[20].

[20] http://ucanr.edu/sites/scmg/files/185639.pdf

Table 11. Monthly Averages and Total Seasonal Amount of Precipitation in Bismarck, North Dakota. U.S.A. Climate Data. Bismarck, North Dakota http://www.usclimatedata.com/climate/bismarck/north-dakota/united-states/usnd0037

Monthly Average			Total Season Precipitation	
	Monthly Totals	Aggregate Total		
January	0.43	0.43	Summer	8.34
Febuary	0.51	0.94	Late Spring	3.66
March	0.87	1.81	Early Fall	2.83
April	1.26	3.07	Total	14.83
May	2.40	5.47		
June	3.19	8.66		
July	2.87	11.53		
August	2.28	13.81		
September	1.57	15.38		
October	1.26	16.64		
November	0.71	17.35		
December	0.47	17.82		

For smaller greenhouses, a manual pump system combined with rain barrels would facilitate crop watering. This system can easily be set up through the use of a large rain barrel, rubber stopper and hose, PVC piping, manual pump, and faucet. The pump will create a negative pressured within the barrel, propelling the water up through the PVC pipe and out of the hose. Alternatively, a simpler—but more labor-intensive—design is to use an open barrel in combination with a watering can for irrigation.

Conclusion

The best practices for water management outlined above could all be implemented on the Standing Rock Reservation as well as on other tribal lands. The authors of this chapter recognize that some of these practices may be more challenging than others due to expense or differing environmental conditions, particularly when it comes to wells. In addition, these best practices work well alongside the best practices identified in other chapters. For example, composting toilets are another method of minimizing household water use, and harvesting rainwater or reusing graywater minimize the use of potable water outdoors for the purpose of producing food. In all, these practices recognize the importance of conserving water resources, not only because one of Standing Rock's primary water sources is being threatened by the Dakota Access Pipeline, but also because of the precious nature of water.

Finance

Introduction

This section briefly summarizes general financial mechanisms available to Native American tribes, current funding options for the Standing Rock tribe, and finally, recommendations for an intermediate timeframe.

Scope of Research

Initially the scope of research on relevant financial mechanisms was an overview of potential mechanisms through the view of a municipality and what would then be available for tribal reservations. If the long-term goal is financial independence, two possible Native-owned & operated financial sources are Native American Bank, N.A. (NABNA)[1] and AMERIND Risk insurance company[2]. NABNA offers secured lines of credit, construction loans, and term loans. AMERIND offers insurance on property and business liability.

A popular method of raising funding is through municipal bonds, a financial funding mechanism which provides tax-exempt interest and/or tax credit to bond holders and provides direct payment to issuers[3]. A new kind of tribal bonds were the Tribal Economic Development (TED) Bonds of the American Recovery Act of 2009. Unlike previous bonds, they can finance tax exempt bonds which also can include "qualified private activity bonds" as long as they satisfy the same requirements that non-tribal state and local governments do. Private activity bonds for Indian Tribal Governments are not tax exempt, therefore the TED bonds provide more options. TED bonds that can qualify include: "financing water finishing facilities, sewage facilities, solid waste disposal facilities, qualified low income residential rental multi-family housing, facilities for the local finishing of electricity and gas or qualified public educational facilities." Several of these are initiatives that the current work plan seeks to address. Another possible bond to utilize is a New Clean Renewable Energy Bond (CREB), which finances renewable energy projects. The issuer pays little to no interest since bond holders will be compensated by the tax credit.

One worthy investment to look into in the future is creating a digital infrastructure. One possible avenue is the AMERIND Critical Infrastructure program which aims to provide high-speed broadband Wi-Fi throughout all the tribal nations. They provide “access to low-cost capital as community and social impact investing for broadband deployment.”

Findings

Currently, $3 million has been earmarked by the Standing Rock Tribal Council to the Eco-Village. There have been a few crowdfunding initiatives including approximately $90,000 for straw-bale housing in the western side of the village. While crowdfunding is a feasible option, it is not always a reliable source of funding.

Conclusions

Foremost, finding a close range of estimated figures is vital to achieving a proper cost--effective analysis (CEA). Having detailed plans on the scale of the Eco-Village and what precisely will be included in the final plan depends on what the tribal residents need. While certain areas can have frameworks, being provided tangible numbers can go a long way in creating a CEA.

Recommendations

Since there is already earmarked funding towards the Eco-Village, the timeframe for the funding is vital. The projects that will be completed in that timeframe will ensure that there is at least some income-generation in the village to create a self-sustaining model.

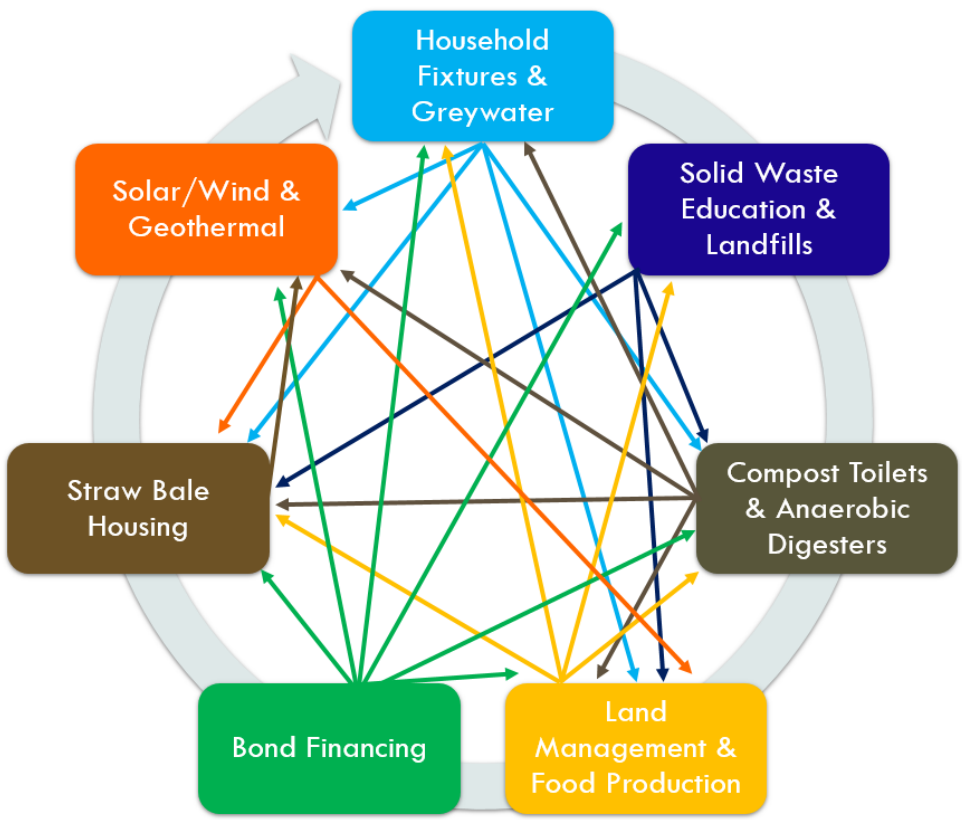
One possible route is through loans and/or applying for a TED or CREB bond for the intermediate timeframe. If the goal is to maintain complete financial autonomy, then this would be a short-term path to having sustainable funds. This would depend on how much risk bondholders are willing to invest in the tribal bonds. If the bonds are graded high, then interest will not be very high. If they are graded low, interest is high and would make the bonds unattractive. This option carries more financial risks yet would likely be a steady stream source of income in contrast to other possible options. If the final step to funding is financial autonomy, there must be a level of self-sustaining funds which this type of financial funding can lead to doing so.

Conclusion

This project aimed to provide sustainability guidelines for the communities at Standing Rock Sioux Tribe. The primary objective was to focus on the nexus and interactions between energy, food, housing, sewage, solid waste, water, and finance. These areas are deeply interrelated and interact in complicated ways (see Figure 19), sometimes complementing each other towards sustainability, and sometimes hindering the achievement of such goals. In this report we suggested how to approach each of these areas with the aim of promoting self-sufficiency and resource independence for the identified communities.

In some of these areas, such as energy, we were able to provide cost-benefit analysis for wind and solar energy projects, as we had data on the projected demand. However, in other areas, due to lack of data and accurate projections, we focused on designing general principles and guidelines that could drive the communities towards a more self-sustained and eco-friendly future. Therefore, this document as a whole should serve as a sound set of general recommendations for these communities, and other similarly situated communities, to guide them towards reaching sustainability goals. This document will also serve as a well-rounded introduction for future capstone projects who might further its usability by providing more site-specific recommendations for individual communities.

Figure 19. The Nexus of Sustainability.



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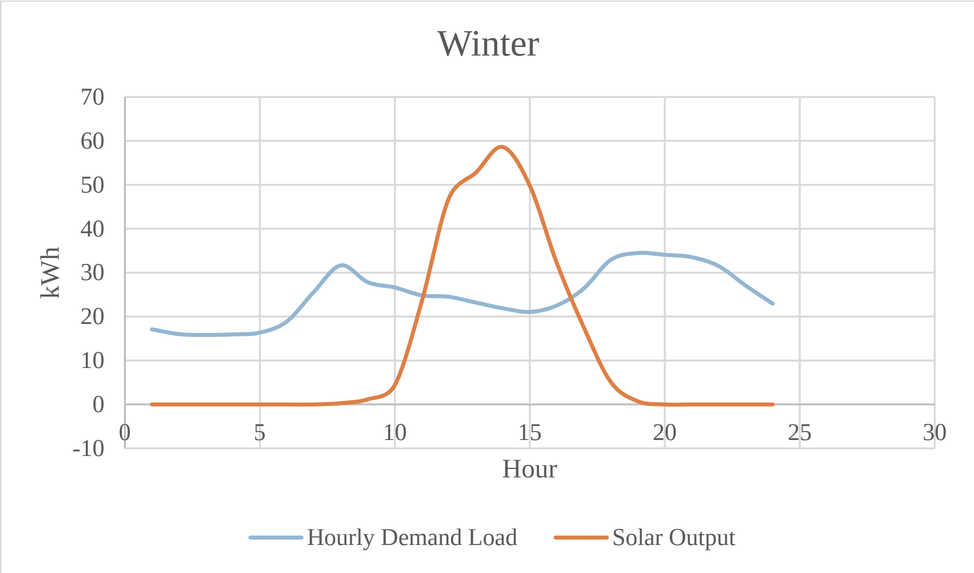
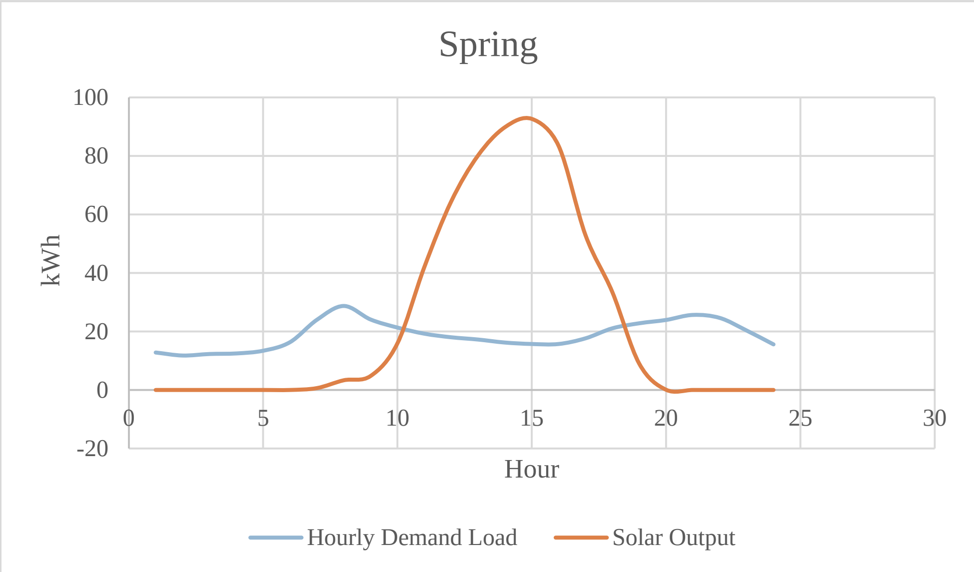
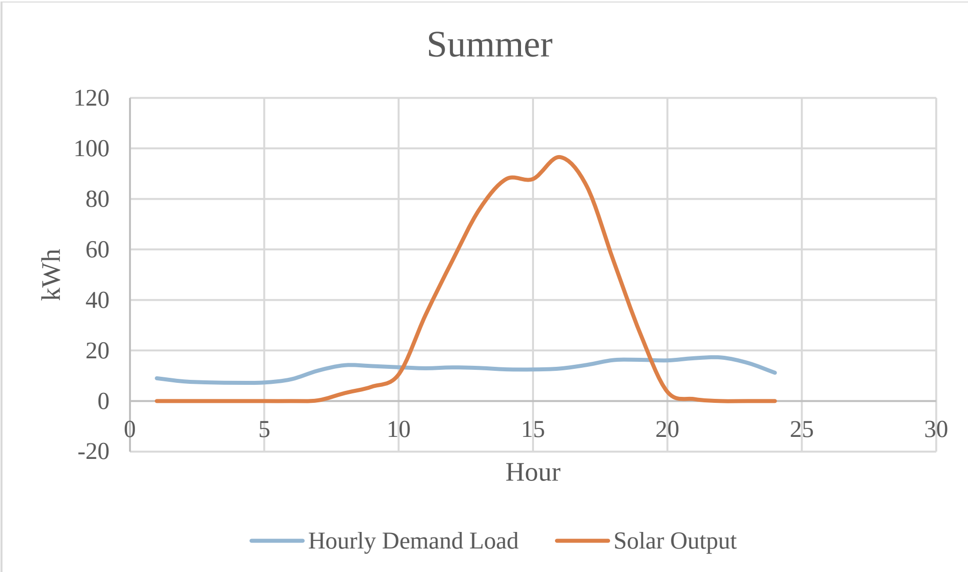
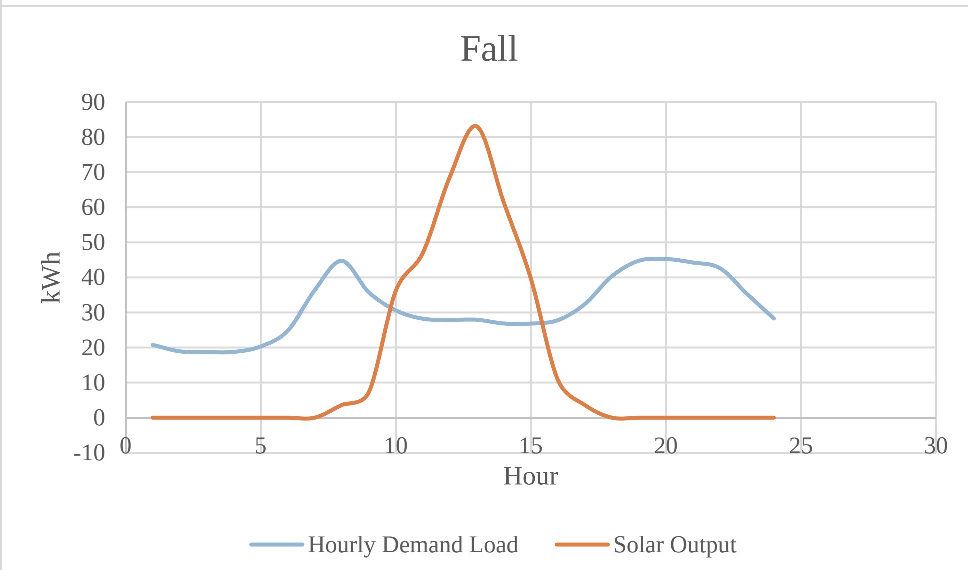
Appendix I: Energy

Solar estimation model: Output matched with demand for 90 kW system






Summer
120
100
80
60
40
20
0
-20
kWh
0
5
10
15
20
25
30
Hour
Hourly Demand Load
Solar Output


Fall
90
80
70
60
50
40
30
20
10
0
-10
kWh
0
5
10
15
20
25
30
Hour
Hourly Demand Load
Solar Output

Appendix II: Food

Contacts

Dr. Wanda Agnew
Faculty and Extension Nutrition Educator (UTTC)
Email address: wagenw@uttc.edu
Phone number: 701-221-1734
Relevance:

Lisa Colombe
CGM Agriculture Services, Olohana Foundation
Email address: reztown@yahoo.com
Relevance:

Luke Gran
Prudenterra (http://www.prudenterra.com/staff)
Email: luke@prudenterra.com
Phone: (515) 451-1202
Relevance: He provided quite a bit of useful information on co-developing food forests with prairie restoration. He is also willing and experienced to do a land survey and planning for a project at the scale of Standing Rock's Eco-Village.

Badger Johnson
Agroforestry & Permaculture Expert (https://www.linkedin.com/in/badgerjohnson)
Email: badgerj@mail.missouri.edu
Phone: (859) 801-3137
Relevance: As a newly certified permaculturalist and agroforestry practitioner, he helped a lot in developing scoping questions and potentially best sustainable practices for food production and timber harvests. He also resided at Sacred Stone Camp during the height of protests in Fall 2016 so he knows the land from direct, albeit different, experience.

Jenny Vasquez
Meskwaki Nation Food Sovereignty Initiative (http://www.meskwaki.org/Local%20Foods.html)
Email: lfc.econdev@meskwaki-nsn.gov
Phone: 641-481-5305
Relevance: We never got to talk on the phone but she would be a peer to anyone at Standing Rock who is looking to grow the tribe's food sovereignty, from household nutrition education to large-scale food production. She could also help with funding since her projects in Iowa secured a federal grant.

Jonah Fertig
Director of Cooperative Food Systems (Cooperative Development Institute)
Email: jfertig@cdi.coop
Phone: 207-615-9970
Relevance: Provided some examples of Native American food co-ops. CDI has also worked with members of various tribes to establish collective farms.

Resources

Common Enterprise Development Corporation is working with Native American communities in North Dakota, South Dakota, and Minnesota around access to food, quality healthcare, and other issues and might be a closer source to the area for cooperative developments.

Democracy Collaborative are working with five Native American groups on creating cooperatives, employee-owned companies, and social enterprises. They are in the final year of a five-year project working with Thunder Valley CDC on Pine Ridge in South Dakota.

Environmental Protection Agency. (2015). Tribal Green Building Toolkit. https://www.epa.gov/green-building-tools-tribes Although more focused on the built environment, this assessment tool includes the following areas related to food production:

- Zoning approaches for preservation of farmland
- Permaculture
- Encourage backyard and community gardens and farmers' markets
- Encourage edible landscaping
- Encourage mixed-use development
- Policies and strategies to provide healthier food options and eliminate food deserts
- Tribal overlay
- Community orchards
- Greenhouses, high tunnels, and other season extenders

First Nations Development Institute is a Native-led non-profit organization whose programs include Nourishing Native Foods & Health, which provides "assistance in the form of financial and technical support, including training materials, to projects that address agriculture and food sectors in Native communities." The Institute also has grantmaking for this program and others. Since 2002, First Nations has awarded 216 grants totaling over $5.6 million to Native organizations dedicated to increasing food access and improving the health and nutrition of Native children and families. The Native Agriculture and Food Systems Initiative (NAFSI) grants are intended to help tribes and Native communities build sustainable food systems such as community gardens, food banks, food pantries and/or other agricultural projects related to Native food-systems control.

Food Distribution Program on Indian Reservations, "is a Federal program that provides USDA foods to low-income households, including the elderly, living on Indian reservations, and to Native American families residing in designated areas near reservations." The program does include quite a bit of processed food and non-cultural foods, but it could be a good bridge program for those households who rely on even more processed and less nutritious foods.

Home Advisor. (2017). How much does it cost to build a greenhouse? http://www.homeadvisor.com/cost/outdoor-living/build-a-greenhouse/ This provides cost estimates for building a greenhouse.

National Agroforestry Center, housed in USDA, "accelerates the application of agroforestry through a national network of partners. Together, we conduct research, develop technologies and tools, coordinate demonstrations and training, and provide useful information to natural resource professionals." They started in the 1930s as a response to the Dust Bowl to help Plains farmers develop tree buffers to improve soil retention, among other things. A recent example of how they apply these benefits to current farmers is through the USDA's Specialty Crop Block Grant Program, which comes to $60 million in FY17 for tree nuts and other nursery crops, as well as fruits and vegetables. This is yet another funding source for Standing Rock's food sovereignty initiative.

North Dakota State University Extension has a number of guides that the Eco-Village could provide for community and home gardeners to understand how to get started:

- Growing Great Vegetables in North Dakota (2000)
- Recommended Vegetable Varieties for North Dakota Gardens (2014)

Plant Hardiness Zones is a tool developed by the USDA, "by which gardeners and growers can determine which plants are most likely to thrive at a location." Standing Rock, proxied by Fort Yates, is Zone 4a –30 to –25 (F).

Ruelle, M. (2011). Plants And Foodways Of The Standing Rock Nation: Diversity, Knowledge, And Sovereignty. This is a Master's Thesis on Native plants and food sovereignty based on action research in Standing Rock. See Chapter 3 for empirical analysis of food and access conditions and Appendix B for particular plants.

Scott, B. (2013, April 1). How much should you plant in your garden to provide a year's worth of food? Retrieved from http://www.wellfedhomestead.com/how-much-should-you-plant-in-your-garden-to-provide-a-years-worth-of-food This is an estimate of the amount of crops needed to provide food for one person per year.

Appendix III: Housing

Table 1. Straw bale sample building cost projections

Straw Bale Sample Building Cost Projections					
Foundation					
Material	Source	Dimension	Unit Cost	Total Units	Total Cost
Sand	HD	1/2 yard	$ 16.00	3	$ 48.00
2x4	HD	96"	$ 2.62	10	$ 26.20
2x4 pressure treated	HD	12'	$ 5.69	14	$ 79.66
Conc Blk Cutout	HD	8x8x16	$ 0.79	220	$ 173.80
Anchor bolt w/w & nut	HD		$ 0.36	55	$ 19.80
Rebar 3/8"	HD	10'	$ 1.39	52	$ 72.28
Felt Tar Paper	HD	36"x36'	$ 15.00	1	$ 15.00
Portland Cement	HD	94 lb	$ 5.69	10	$ 56.90
Total Foundation					$ 337.78
Compression Plates					
Material	Source	Dimension	Unit Cost	Total Units	Total Cost
OSB	HD	4 x 8	$ 18.95	5	$ 94.75
2x4	HD	96"	$ 2.62	20	$ 52.40
2x6	HD	8'	$ 4.30	10	$ 43.00
Mending Plate	HD	2x4	$ 0.32	20	$ 6.40
Total Compression Plates					$ 196.55
Trusses					
Material	Source	Dimension	Unit Cost	Total Units	Total Cost
2x4	HD	96"	$ 2.62	32	$ 83.84
2x4	HD	16'	$ 5.65	13	$ 73.45
Mending Plate	HD	2x4	$ 0.32	120	$ 38.40
Tie Plate	HD	3x7	$ 0.52	30	$ 15.60
Total Trusses					$ 211.29
Roof					
Material	Source	Dimension	Unit Cost	Total Units	Total Cost
2x4	HD	96"	$ 2.62	32	$ 83.84
Plywood 4x8	HD	1/2 cdx	$ 21.57	2	$ 43.14
Galv Steel Roof	HD	12'x26"	$ 10.98	28	$ 307.44
Galv Roof Edge	HD	10'	$ 1.98		$ -
Wood Roof Closure	HD	6'	$ 1.98	8	$ 15.84
Total Roof					$ 450.26
Walls/Plaster					
Material	Source	Dimension	Unit Cost	Total Units	Total Cost
Sand	HD	1/2 yard	$ 16.00	5	$ 80.00
All Thread 3/8"	HD	6'	$ 3.90	32	$ 124.80
Clay		1 ton	$ 10.00	10	$ 100.00
Straw Bales		2 string	$ 5.00	180	$ 900.00
Total Wall					$ 1,204.80
					$ 2,400.68

Table 2. Construction and labor costs for the straw bale demonstration project at Ganado

Table Two. Construction and Labor Costs for the Straw-bale Demonstration Project at Ganado

	Labor	Material	Labor & Material
Footing	$ 576	$1,022	$1,598
Foundation	2,500	2,938	5,438
Slab	20	3,435	4155
Strawbale	540	1,032	1,572
Adobe	1,920	1,575	3,495
Bond Beam	576	1,022	1,598
Cripple Wall (Framing)	720	3,990	4,710
Insulation	576	664	1,240
Roof Structure	4,032	5,233	9,265
Stuccoing	1,440	3,430	4,870
Interior Walls	864	1,998	2,862
Interior Finishes	1,152	1,615	2,767
Ceiling Finishes	1,440	1,009	2,449
Rough Plumbing	576	621	1,197
Rough Wiring	576	490	1,066
Plumbing Trimming	384	1,041	1,425
Electrical Trimming	384	1,252	1,636
Cabinets	384	1,195	1,579
Floor Finishes	440	1,188	1,628
Fixed Equipment/Wood Stove	1,200	1,296	2,496
Totals	$21,000	$36,046	$57,046

Table 3. Cost estimations for a 1,000 square feet container house (not including land and foundation)

	Standard 20 foot	Standard 40 foot	High cube 20 foot	High cube 40 foot	Ref.
Size					
Dimensions	20 x 8 x 8	40 x 8 x 8	20 x 8 x 9	40 x 8 x 9	
Square feet	160	320	160	320	
Unit price ($US per container)					
Used	2,100	2,850	2,200	2,950	1
New	3,000	5,600	3,200	5,800	1
Delivery cost					
Unit price ($US per mile)	1.33	2.6	1.33	2.6	2
Within 300 mile delivery ($US)	399	780	399	780	3
Modification cost ($US)					
Minimum base cost	10,000	10,000	10,000	10,000	4
Average base cost	15,000	15,000	15,000	15,000	4
Estimated minimum costs in total ($US)					
Used container	12,499	13,630	12,599	13,730	
New container	13,399	16,380	13,599	16,580	
Estimated minimum costs in total ($US) for 1,000 sq ft					
Used container	78,118.75	42,593.75	78,743.75	42,906.25	
New container	83,743.75	51,187.50	84,993.75	51,812.50	

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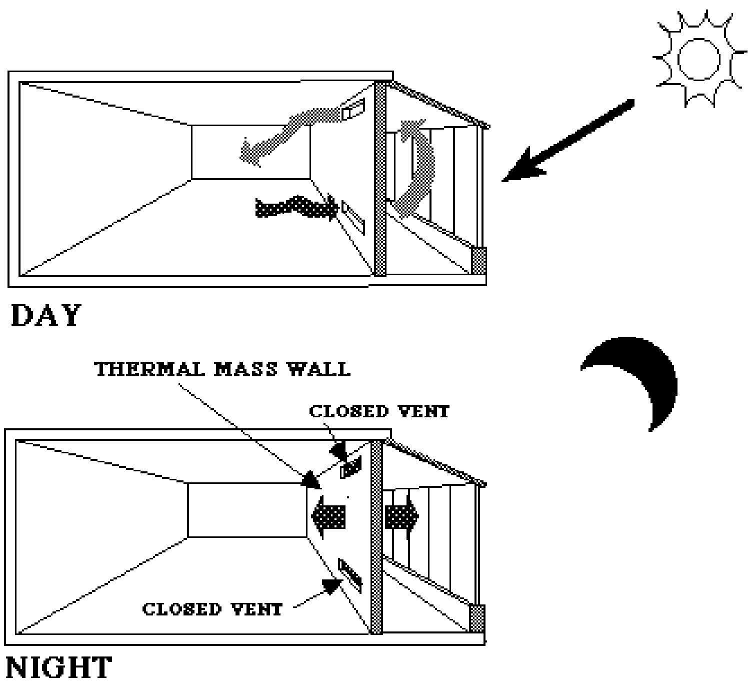
3. Nearest dealers to Standing Rock, http://www.uscontainersales.com/nd/fargo.php
4. http://www.24hplans.com/top-20-shipping-container-home-designs-and-their-costs/

Figure 1. A straw bale house example: the Haslow House

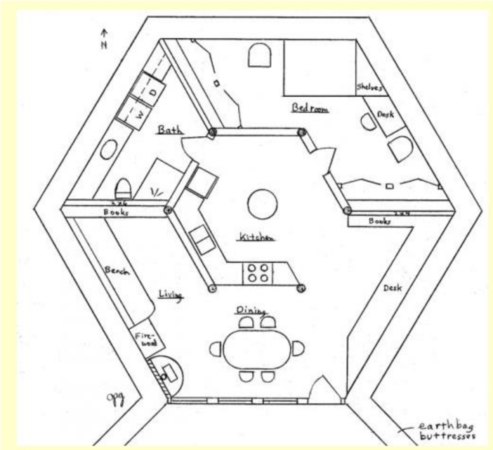
Source: Henry, M. (2012, October 7).

Figure 2. Passive solar design

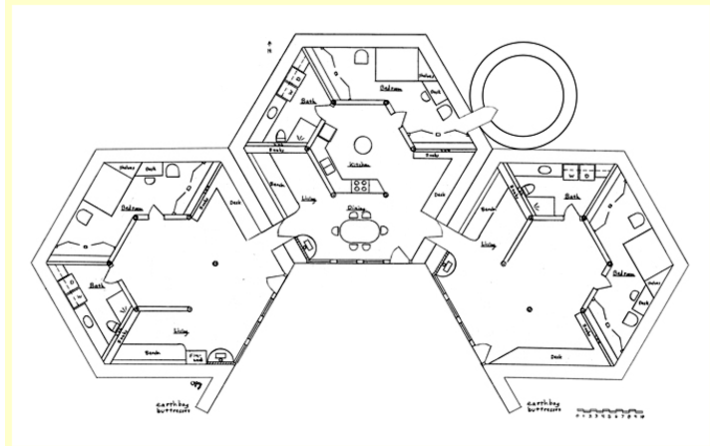


Source: Passive solar design (2017). Retrieved from Sustainable Sources: http://passivesolar.sustainablesources.com/

Figure 3. Earth lodge design visualization



Floor Plan

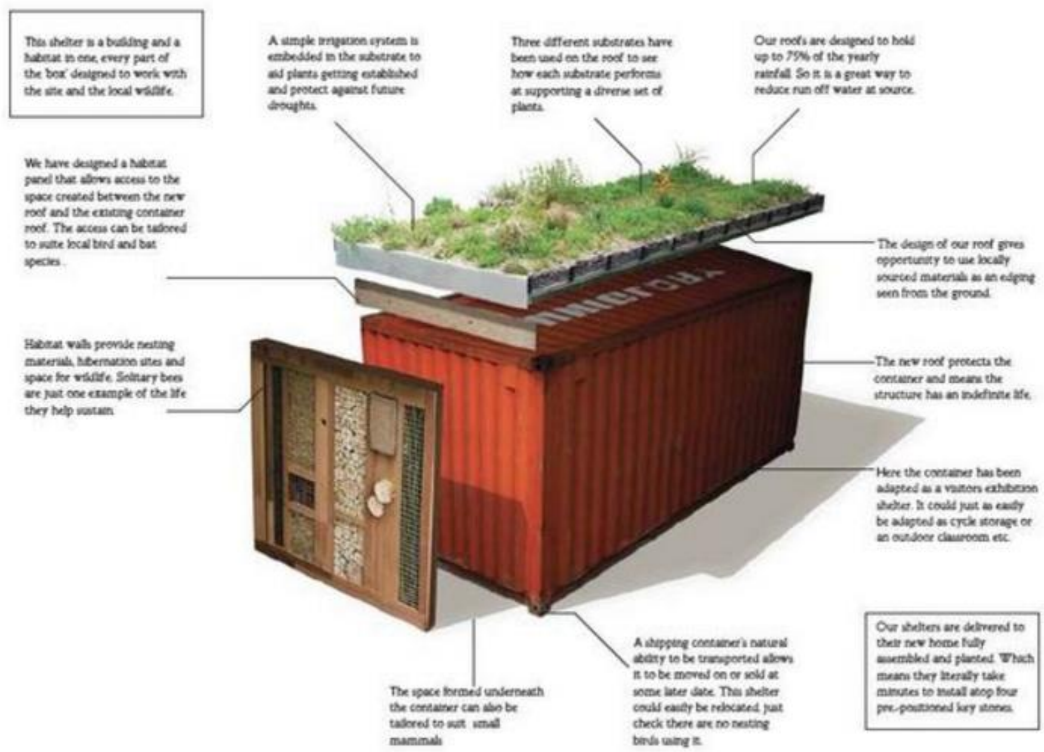


Earth Lodge Cluster Floor Plan

Figure 4. Visualized design of container house with solar and wind power

Source: Meinhold, B. (2010, March 10).

Figure 5. Visualized design of container house roof garden



Source: Green roof shelters. (2010, November 9).