BIOMASS FEASIBILITY STUDY FOR A WOOD TO ENERGY FACILITY AT CAMP NAVAJO, ARIZONA

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Arizona Department of Emergency and Military Affairs

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Final Report
February 18, 2019

ACKNOWLEDGMENTS

The authors wish to thank a number of individuals and organizations for their significant efforts in support of this project:

- Gerald Paulus, Project Manager, AZ Department of Emergency and Military Affairs
- Timothy Phillips, Ordinance Operations, AZ Department of Emergency and Military Affairs
- Supervisor Matt Ryan, Coconino County
- Supervisor Art Babbott, Coconino County
- Janet Johnson, AZ Army National Guard
- Nicholas Kainrath, AZ Army National Guard
- Tony D'Angelo, AZ Department of Emergency and Military Affairs
- Dorenda Coleman, AZ Army National Guard
- Jay Smith, Coconino County
- Michele Ralston, Coconino County
- Dick Fleishman, Coconino National Forest
- Roger Joos, Williams Ranger District
- Samantha Flores, Williams Ranger District
- Cary Thompson, Coconino National Forest
- Patrick Rappold, Forest Health Cooperative Extension, University of Arizona
- Aaron Green, AZ Department of Forestry and Fire Management
- Keith Pajkos, AZ Department of Forestry and Fire Management
- Patrick Rappold, University of Arizona Extension
- Wally Covington, Ecological Restoration Institute, Northern Arizona University
- Diane Vosick, Ecological Restoration Institute, Northern Arizona University
- Han-Sup Han, Ecological Restoration Institute, Northern Arizona University
- Jeff Halbrook, Ecological Restoration Institute, Northern Arizona University
- Joseph Dahms, Natural Resources Conservation Service
- Matt Morales, Cinder Lake Landfill
- Doug Owens, Lake Ellen Transfer Station
- Paul Summerfelt, Flagstaff Fire Department
- Matt Millar, Operations Specialist, Flagstaff Watershed Protection Project
- Adam Cooley, New Life Forest Products
- Steve Horner, Campbell Global
- Jan Ribelin, High Desert Investment
- Devon Suarez, Suarez Logging
- Kenneth Cox, Northern AZ Procurement Company
- James and Keith Perkins, Perkins Timber Harvesting
- Chris Lowman, AZ State Lands Department

Listed below are members of the TSS/PES implementation team:

- Tad Mason, Project Manager, TSS Consultants
- Jim Beck, Precision Energy Systems
- Fred Tornatore, TSS Consultants
- Daren Anderson, The NESCO Group

ABBREVIATIONS

4FRI	4 Forest Restoration Initiative
AADT	Average Annual Daily Traffic
AC	Activated carbon
ACC	Arizona Corporations Commission
ADC	Alternative daily cover
ADEQ	Arizona Department of Environmental Quality
ADFFM	Arizona Department of Forestry and Fire Management
ADOT	Arizona Department of Transportation
ADP	Area Development Plan
APS	Arizona Public Service
ASLD	Arizona State Lands Department
AZARNG	Arizona Army National Guard
AZDES	Arizona Discharge Elimination System
BACT	Best available control technology
BFB	Bubbling fluidized bed
BDMT	Bone dry metric ton(s)
BDT	Bone dry ton(s)
BLM	Bureau of Land Management
BNSF	Burlington Northern Santa Fe Railway
Btu	British thermal unit
CCF	Hundred cubic feet
CHP	Combined heat and power
CFB	Circulating fluidized bed
CO	Carbon Monoxide
CUP	Conditional use permit
dB	Decibels
DBH	Diameter at breast height
DoD	Department of Defense
DSCR	Debt service coverage ratio
EA	Environmental assessment
EIS	Environmental impact statement
EQIP	Environmental Quality Improvement Program
ERI	Ecological Restoration Institute
ESP	Electrostatic precipitator
F	Fahrenheit
FIA	Forest Inventory Analysis
FIR-BBER	Forest Industry Research, Bureau of Business and Economic Research
FWPP	Flagstaff Watershed Protection Project
FSA	Fuel Sourcing Area
GEP	Good Earth Power
GIS	Geographic information system
GPD	Gallons per day
GPM	Gallons per minute
GT	Green ton(s)
HFRA	Healthy Forests Restoration Act
HVAC	Heating ventilation and air conditioning

ICE	Internal combustion engine
IMP	Camp Navajo Integrated Management Plan
IUOE	International Union of Operating Engineers
JLUS	Coconino County Joint Land Use Study
Kv	Kilovolts
kWh	Kilowatt hour
LCFS	Low Carbon Fuel Standard
MBF	Thousand board feet
MMBtu	Million British thermal units
MMSF	Million square feet
mph	Miles per hour
MSW	Municipal solid waste
MW	Megawatt
MWh	Megawatt hour
NAU	Northern Arizona University
NAFF	Northern Arizona Forest Fund
NEPA	National Environmental Policy Act
NLFP	NewLife Forest Products
NF	National Forest
NOI	Notice of intent
NOFS	Navy Observatory Flagstaff Station
NOx	Oxides of nitrogen
NRCS	Natural Resources Conservation Service
O&M	Operation and maintenance
OSB	Oriented strand board
OOD	Ordnance Operations Department
ORC	Organic Rankin Cycle
PC	Planned Community Zone
PFP	Perkins Forest Products
PG&E	Pacific Gas and Electric
PJ	Pinyon and juniper grasslands
PM	Particulate matter
PPA	Power purchase agreement
PPH	Pounds per hour
PSD	Potential for significant deterioration
PTC	Production Tax Credit
PURPA	Public Utility Regulatory Policy Act
RDF	Refuse derived fuel
REC	Renewable Energy Certificate
REST	Renewable Energy Standard and Tariff
RFI	Request for information
RFS	Request for offers
RPI	Rural Policy Institute
RPS	Renewable Portfolio Standard
SRE	Sustainable Renewable Energy
SOx	Oxides of sulphur
SRP	Salt River Project
SWPPP	Storm Water Pollution Prevention Plan

TSS	TSS Consultants
USDA	United States Department of Agriculture
US DOE	United State Department of Energy
US EPA	United State Environmental Protection Agency
USFS	USDA Forest Service
WWTP	Waste water treatment plant
4FRI	4 Forest Restoration Initiative

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INTRODUCTION

The Arizona Department of Emergency and Military Affairs (AZDEMA) retained TSS Consultants to provide services in support of a biomass feasibility study for siting a wood-to-energy facility on or near Camp Navajo. Camp Navajo is a 28,413 acre Army National Guard training site and Department of Defense storage site located 12 miles west of Flagstaff, Arizona. Approximately 18,700 acres of Camp Navajo is ponderosa pine dominated forest cover.

The Camp Navajo Forest Management Plan identifies the need to thin 14,000 acres over the next 10 years. In addition, the USDA Forest Service (USFS) has implemented the Four Forest Restoration Initiative (4FRI) that calls for treatment of between 30,000 and 50,000 acres per year over 10 years. Other landowners and agencies with plans to reduce forest fuels include the Arizona State Land Department, City of Flagstaff, and various private landowners.

An overriding concern for northern Arizona natural resource managers is the ecologic and economic impacts of catastrophic wildfire. In recent years large wildfire events have severely impacted Arizona:

- 2002 Rodeo-Chedeski Fire – 462,614 acres, $308,403,000 total cost
- 2010 Shultz Fire – 15,000 acres, $140,000,000 total cost
- 2011 Wallow Fire – 538,049 acres, $109,000,000 total cost
- 2013 Yarnell Hill Fire – 8,400 acres, 19 killed, $662,000,000 total cost

In total, these four fires cost over $1.2 billion to suppress, restore damaged sites and compensate families of firefighters killed in the Yarnell Hill Fire. A significant factor impacting fire behavior in Arizona is the current overstocked conditions of forest landscapes. Improved market conditions for forest biomass will facilitate economic treatment and removal of excess forest biomass. This in turn will increase the pace and scale of hazardous fuels treatment activities.

This study reviewed a variety of technologies and the associated feasibility of siting a commercial-scale wood-to-energy facility at Camp Navajo that will assist the Arizona Army National Guard in achieving energy resiliency and energy security as well as improve forest health and promote economic development in Northern Arizona. Key objectives of this feasibility study are outlined below.

- Analyze the long-term availability of forest feedstock tributary to Camp Navajo. Confirm current infrastructure, land ownership, transportation system and costs to source forest feedstocks.
- Review five promising biomass wood-to-energy technologies and recommend the most appropriate technology.
- For the recommended technology, confirm optimal scale of the facility (power and heat output). Confirm optimal wood material processing methodology that will provide fuel meeting the recommended technology fuel specifications.
- Estimate capital expense for installation of the recommended technology (all in cost). Estimate cost to operate and maintain this facility (annual O&M costs).
- Determine the opportunity to market power and heat produced (and other byproducts).

- Conduct financial analysis (including return on investment, payback period) to assess economic viability of the wood-to-energy business model.
- Conduct environmental review of recommended technology to confirm environmental impacts (including air emissions, water usage, water discharge, ash output, truck traffic).
- Identify commercial-scale value-added technologies that could be collocated with the wood-to-energy facility to optimize economic utilization of the site (e.g., OSB facility, wood processing cluster, solar/wind resources).

SITE CONDITIONS ANALYSIS

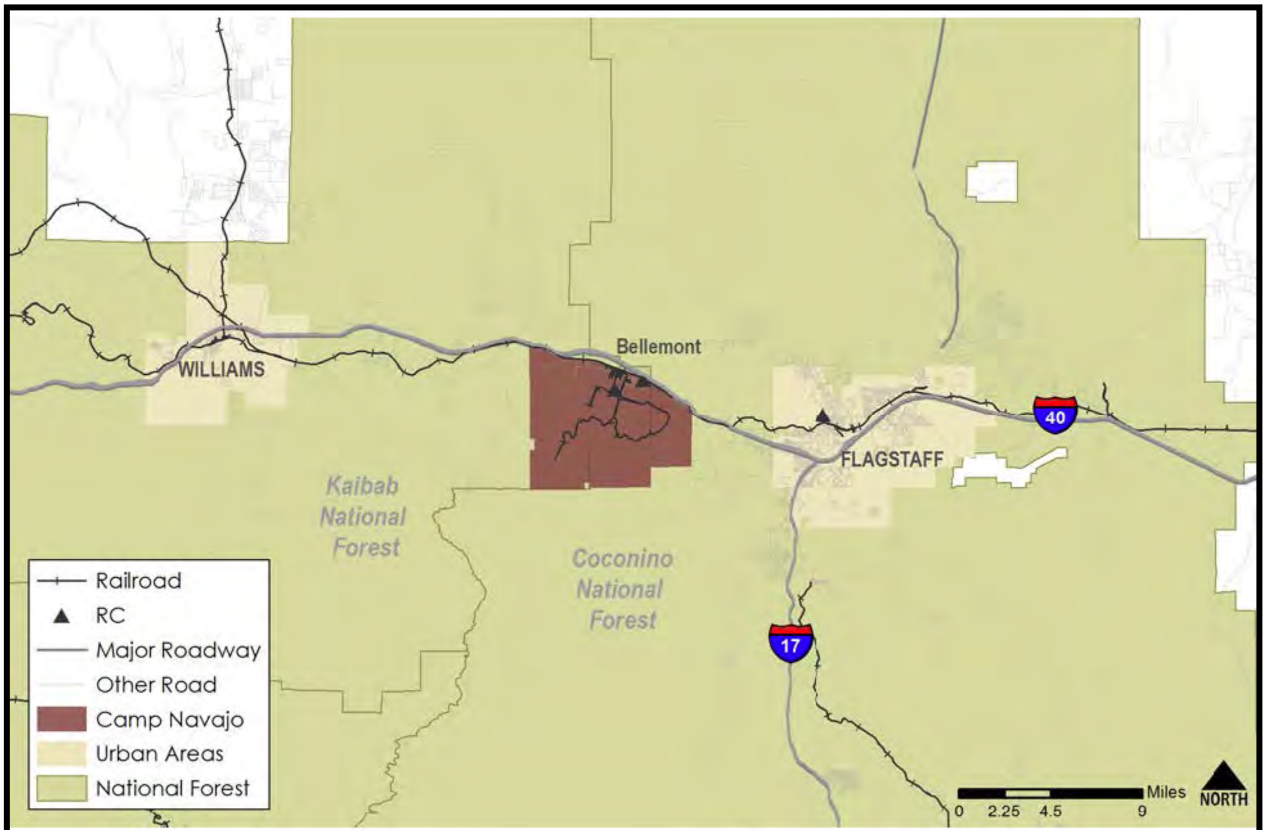
The Camp Navajo site has several significant attributes to support the siting of a commercial-scale bioenergy facility. Overall, the site is well positioned to function in the capacity of host for long-term leases with industrial clients, as it has done in the past for an industrial rubber company. This approach is similar to industrial campuses developed at ports of entry[1] throughout the West Coast. A major benefit of these campuses is it allows the grouping of industrial clients so they can share a common source of industrial grade utilities, including rail spurs, which allows lower cost to build a facility via economies of scale. In addition, it allows industrial zoning to be concentrated in a common area, which facilitates more efficient use of existing transportation infrastructure.

Land Use

Camp Navajo is located in north central Arizona immediately south of the unincorporated town of Bellemont (Coconino County) approximately 12 miles west of Flagstaff and 125 miles north of Phoenix. It can be accessed off of Interstate 40 (I-40) at Exit 185. Its location is illustrated in Figure 1.

[1] The Port of Morrow, located in Boardman, OR has 2,500 acres of industrially zoned land, titled the 'Boardman Industrial Park' used by Lamb-Weston, Barenburg USA, and many other industrial facilities. Companies located in the industrial campus cover a range of industries, include food processing, agricultural export, chip and biomass export, and large-scale cold storage.

Figure 1. Camp Navajo Location



Source: Camp Navajo Vision Plan, 2017

Camp Navajo is the largest military installation in northern Arizona. Operated by the Arizona Army National Guard (AZARNG), it is the largest of the AZARNG installations at 28,347 acres. Its principal activities are as a military training site and ordnance storage depot. As a training site, it serves all branches of the military, both active and reserve. As a storage depot, the Camp's extensive acreage accommodates thousands of acres of military ordnance storage for a variety of Department of Defense (DoD) customers.

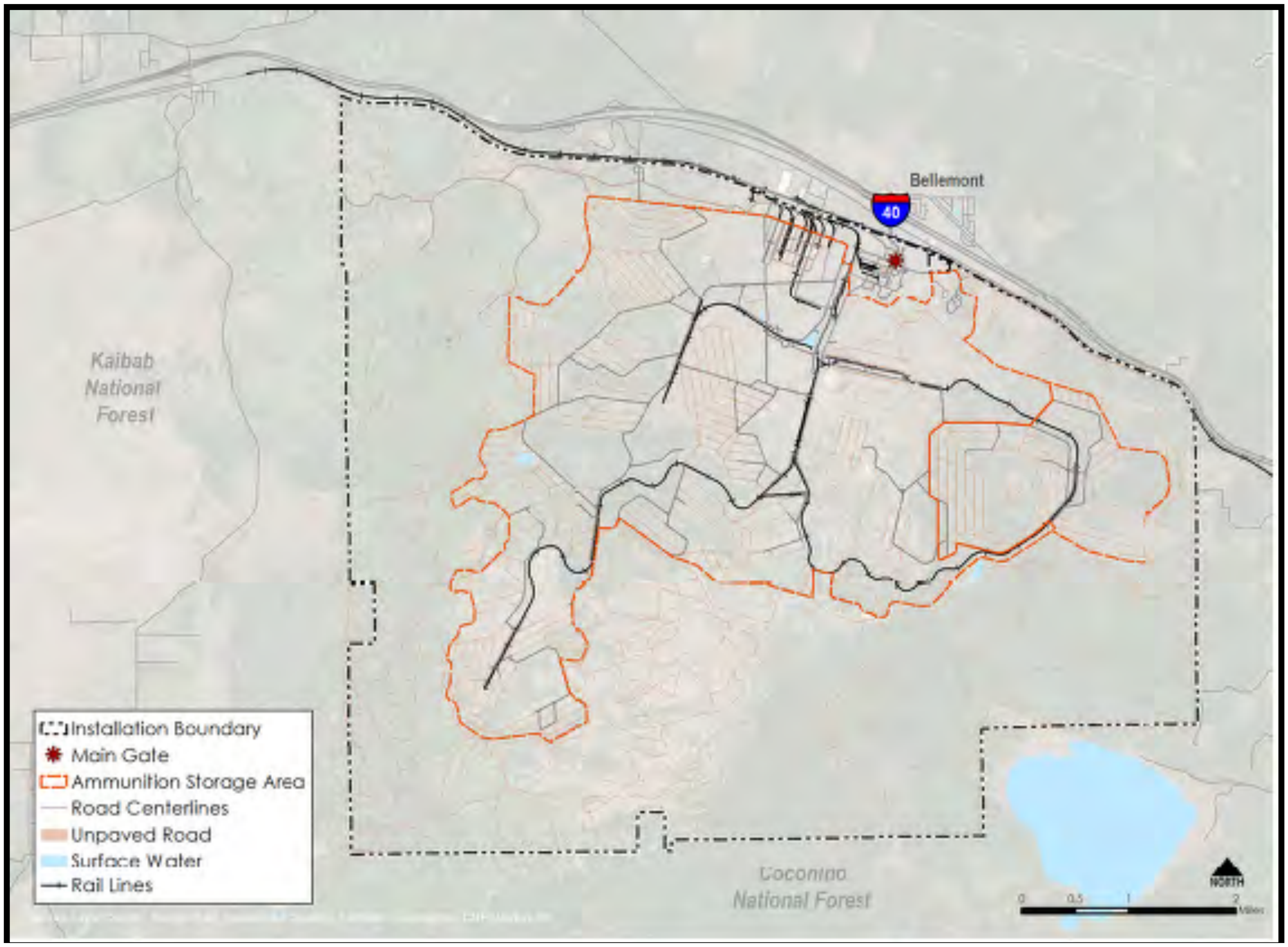
This military installation was established in 1942 as a supply depot and multi-service training site. Prior to military use, the land was managed for homesteads, ranching, and timber. In 1942, privately held parcels were purchased and combined with federal land (Coconino NF and Kaibab NF) to form the Camp Navajo Ordnance Depot (now known as Camp Navajo). Camp Navajo is owned by the Army Corp of Engineers, which has a long-term lease agreement with the Arizona Army National Guard (AZARNG). Historically, the AZARNG has actively managed forest resources at Camp Navajo since the early 1950s.

Camp Navajo can also be accessed from the Burlington Northern Santa Fe double-track rail line along its northern border. Rail spurs lead into Camp Navajo allowing the transfer of rail cargo to the installation's internal rail network and other transport modes (see Figure 2). The rail system has been recently upgraded and has capacity to serve industrial customers.[2] There are also

[2] Camp Navajo Master Plan, December 2017 and confirmed by the Garrison Commander.

ongoing discussions within both the Coconino Joint Land Use Study (JLUS) planning process and the Bellemont Area Plan Update planning process regarding the access to Camp Navajo via the overpass at Exit 185 on I-40. The Arizona Department of Transportation (ADOT) has proposed widening the overpass to three lanes; however, the JLUS planning process is encouraging that it be expanded to five lanes.

Figure 2. Camp Navajo Installation Overview



Source: Camp Navajo Master Plan, December 2017

Current and Planned Land Use at Camp Navajo

<u>Current Land Use</u>

The current land use of Camp Navajo is dominated by its two principal missions,[3] which include:

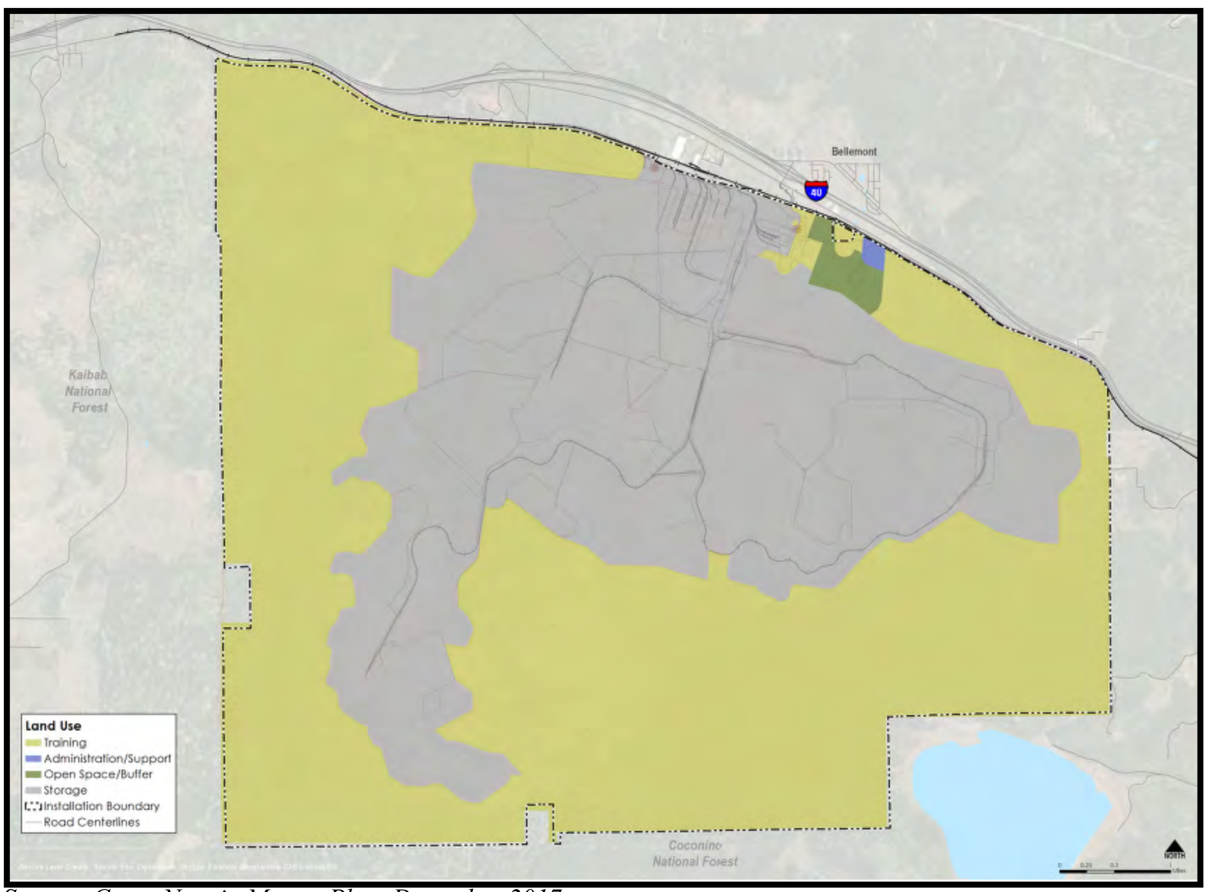
[3] Camp Navajo Master Plan, December 2017.

Operating a National Guard training site – Camp Navajo offers significant training services and capabilities and can accommodate several battalion size units (approximately 600 people) for military training onsite.

Providing depot-level storage and service for both military and private customers – The installation's capacity for general warehouse space and storage of military ordnance exceeds 2.3 million square feet. Storage space structures consist of 778 igloo type magazines. Although these structures have systems to insure their security, there are several categories of items that cannot be stored at the base – nuclear and radiological materials, biological agents, and chemical agents.

Areas dedicated to training and storage are shown on Camp Navajo's land use map in Figure 3. Land use is structured around these two principal missions with approximately 57.5% (16,344 acres) for training, and 41.7% (11,854 acres) for storage. The remainder (149 acres) is for adminstration and support and an open space/buffer.

Figure 3. Camp Navajo Land Use



Source: Camp Navajo Master Plan, December 2017

Camp Navajo currently has several users/tenants, which include the following.

AZDEMA:

- Camp Navajo Garrison Command – Commands, operates, manages, and administers the use of the installation.
- 194th M FFM DET – Provides fire-prevention and protection, aircraft crash response and rescue, wildland firefighting assistance, and hazardous materials spill response.
- Field Maintenance Shop #6 – Performs field maintenance for all types of ground surface equipment issue to the Army National Guard.
- 819th Sappers – Executes, coordinates, and conducts a variety of mobility and survivability tasks, and provides support to general engineering missions.
- 856th Military Police Company.
- Ordnance Operations – Provides depot-level storage services for DoD customers.
- Arizona Department of Emergency and Military Affairs – Consists of the Arizona National Guard (Air, Army, Joint Task Force), the Division of Emergency Management and the Division of Administrative Affairs.

Others:
- Veterans Cemetery (deeded to Veterans Affairs by US Army Corp of Engineers).
- National Oceanic and Atmospheric Administration – U.S. Weather Service Flagstaff Field Office.

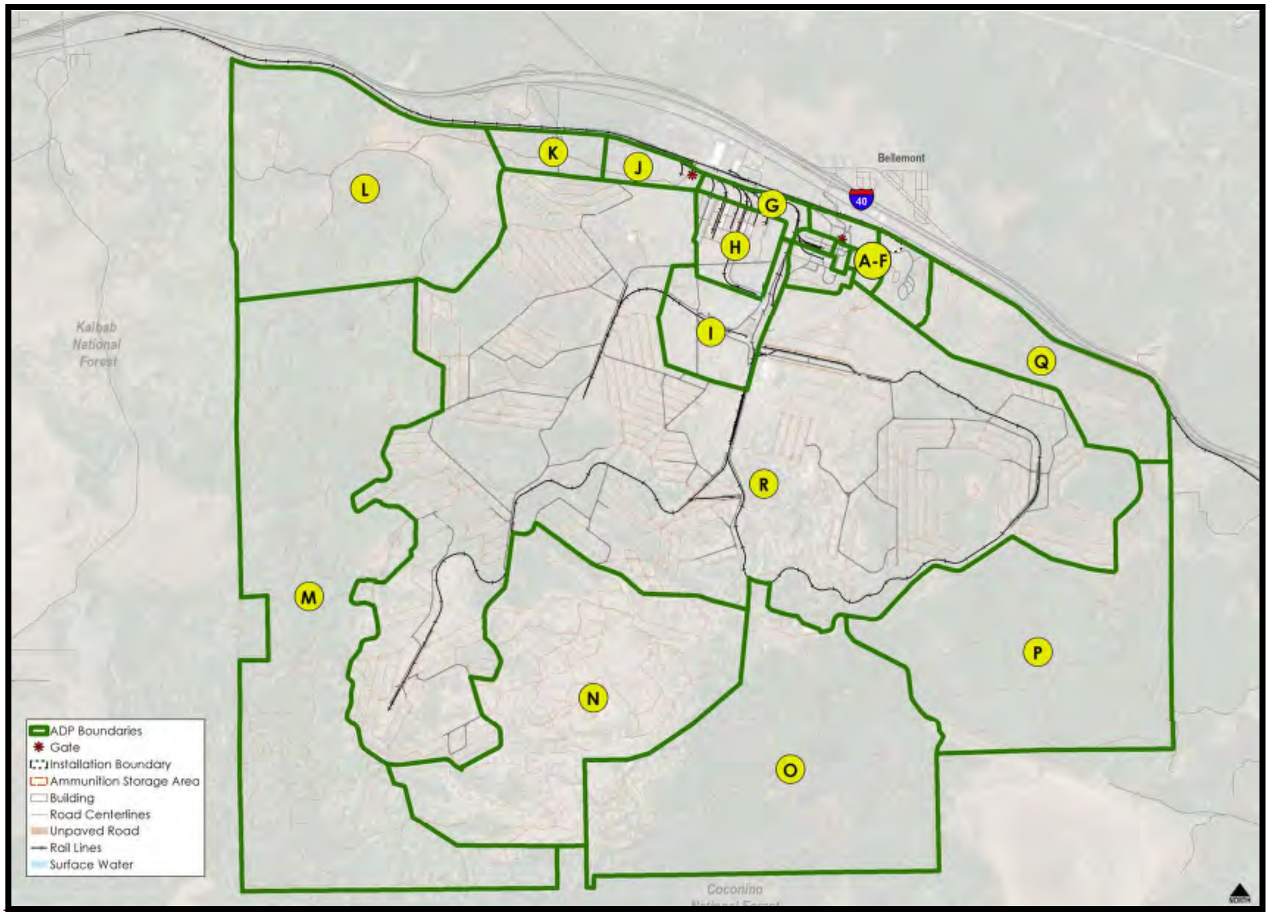
Of particular interest for this feasibility study is that portion of Camp Navajo known as the 200 Area (designated with its own Area Development Plan in the 2017 Installation Master Plan – further discussed below). This area appears to be capable of supporting a bioenergy facility; however, the condition of the existing infrastructure including electric, water, wastewater and natural gas is not known and warrants further study.

<u>Planned Land Use</u>

Future land use within Camp Navajo is being guided primarily by the Camp Navajo Installation Master Plan (IMP), which was completed in December 2017. This Plan, which defines the course of action for the installation, was built on information collected from numerous stakeholders. The IMP is considered a sustainable future land and facility use plan, identifying the most effective and efficient uses of the Camp Navajo properties for the AZARNG to continue to support both the training and storage missions.

The IMP delineated a series of Area Development Plans, all keyed to different portions of the facility, within which future development and activities/functions should be organized. Figure 5 shows these functional areas within the base confines. The 200 Area is located in the northern portion of the base and is designated as “H” in Figure 4.

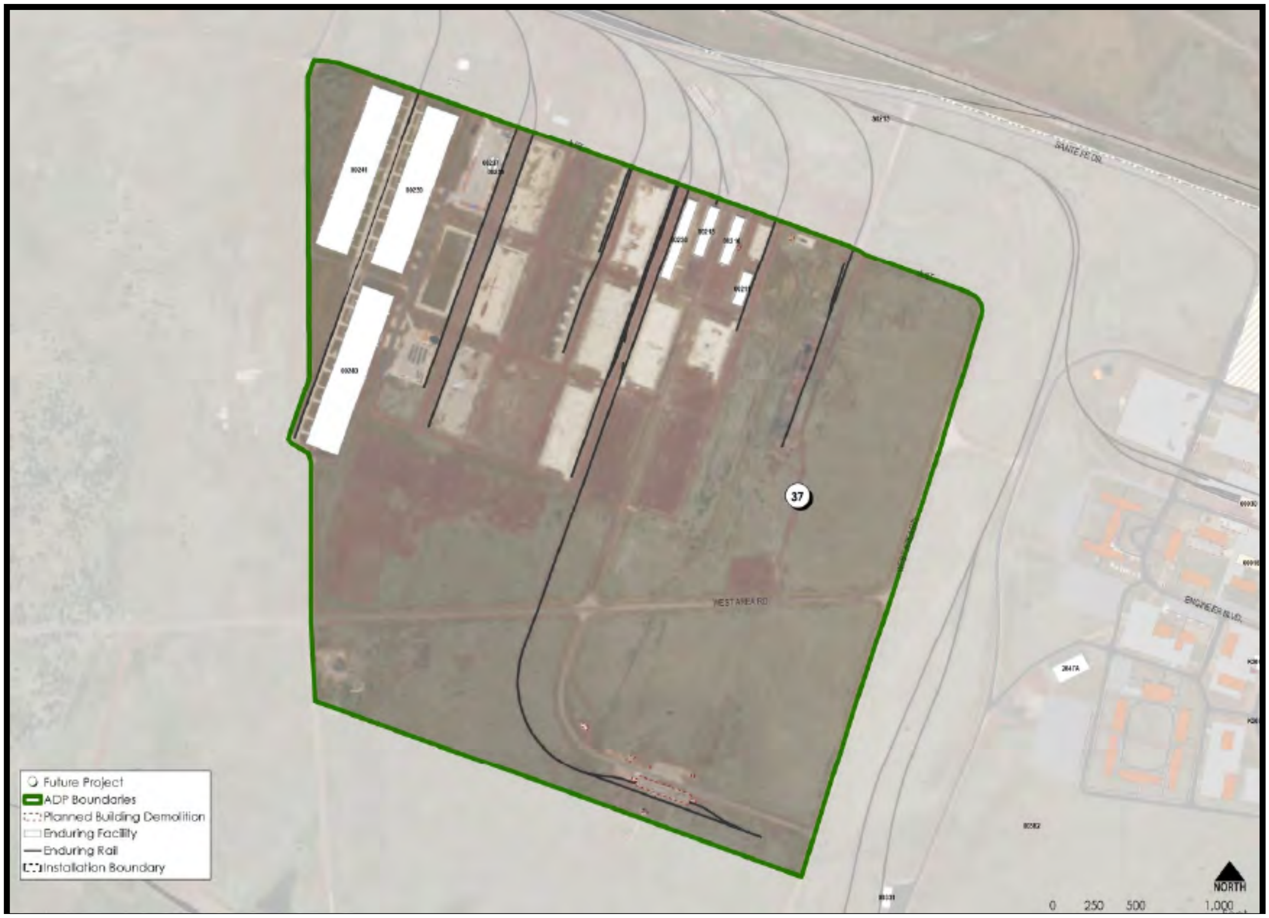
Figure 4. 200 Area Location



Source: Camp Navajo Installation Master Plan, December 2017

The IMP designated the 200 Area has the *"most likely location for the future biomass facility."* Outside of a biomass power generation facility, there are few other proposed projects for the 200 Area. The 200 Area is currently a collection of several large-scale warehouses and locations of former warehouses with open land (primarily in the southern half). The area is also laced with rail spurs and roadways as shown in Figure 5. Currently the area is used by the Ordnance Operations Division (OOD).

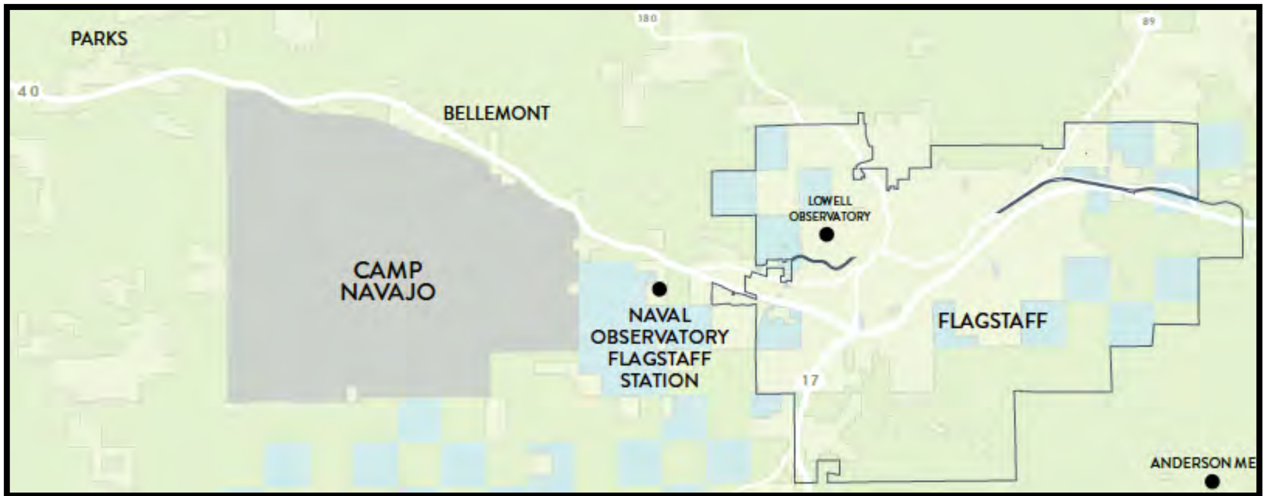
Figure 5. 200 Area Detail



Source: Camp Navajo Installation Master Plan, December 2017

Camp Navajo is also currently engaged in the Coconino JLUS process. The JLUS is a land use planning effort bringing Coconino County, the City of Flagstaff, Camp Navajo, and the Naval Observatory Flagstaff Station together to develop a policy framework and implementation measures to support the local and regional community and environment, as well as the military mission of Camp Navajo. The study area is illustrated in Figure 6. The study also includes the Coconino and Kaibab National Forests, and the Navajo, Hopi, and San Juan Southern Paiute Sacred Lands.

Figure 6. Joint Land Use Study Area



Source: Coconino JLUS, Joint Council Meeting, June 4, 2018

Recent presentations for the JLUS process have indicated that Camp Navajo is actively seeking to revitalize on-base commercial and industrial development in the 200 Area. This included biomass utilization facilities such as oriented strand board (OSB) manufacturing or a bioenergy plant.[4]

Land Use and Ownership Surrounding Camp Navajo

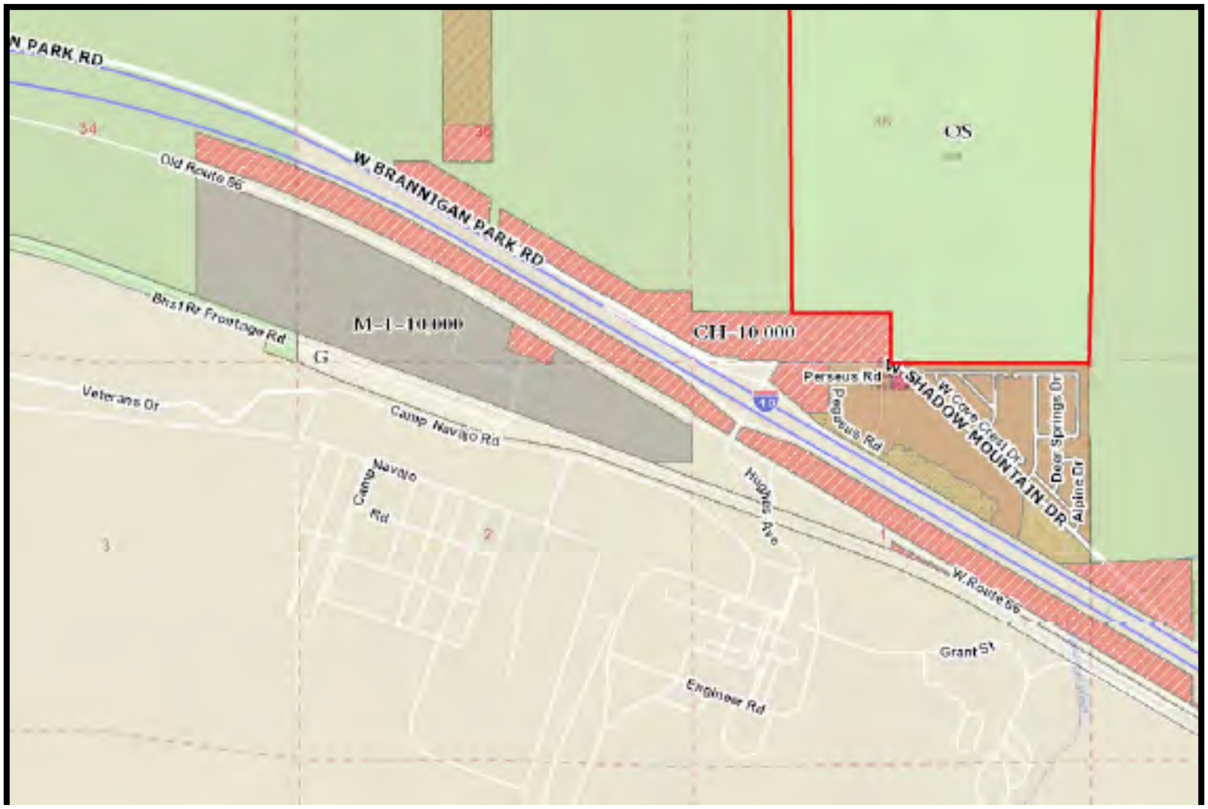
Camp Navajo is located exclusively within the borders of Coconino County. The Camp Navajo's 28,347 acres are approximately 0.2% of the total land mass within Coconino County.

The Coconino and Kaibab National Forests, Arizona State Trust lands, and small private land holdings (mostly at the southeast corner) currently border Camp Navajo. Adjacent to the northern border are portions of historic U.S. Route 66, I-40, and the Burlington Northern Santa Fe railway. Just north of I-40 are a major truck stop, a residential area known as Flagstaff Meadows, and a commercial area, which together are considered the unincorporated community of Bellemont.

Coconino County industrially zoned land is also adjacent to the northern border of Camp Navajo. This adjacent industrially zoned land, designated as M-1-10,000 is shown in Figure 7. Bioenergy facilities generally fit best in industrial zoned properties (additional discussion below in the Environmental Permitting section). Figure 8 is a photograph of the western half of the industrially zoned property in Bellemont (approximately 90 to 100 acres of vacant land). In the right side of the photo in the background are existing industrial facilities, and in the center background are the 200 Area warehouses on Camp Navajo.

[4] Coconino JLUS, Joint Council Meeting, June 4, 2018.

Figure 7. Industrial Zoned Land in Bellemont Area



Source: Coconino County Planning Department Geographic Information System

Figure 8. Photo of Industrial Zoned Land in Bellemont

Source: TSS Consultants

The next closest industrially zoned land is approximately 9 miles southeast on Flagstaff Ranch Road between I-40 (Exit 192) and Historic Route 66. However, most of this industrially zoned land appears occupied, and there is likely not enough vacant land (20 acres) for a bioenergy plant and feedstock storage area.

Findings

There is suitable land available within Camp Navajo for a commercial-scale biomass energy facility based on the IMP and proposed land uses therein. Industrially zoned land outside of Camp Navajo, suitable for a commercial-scale biomass energy facility (and feedstock storage), is located directly adjacent to the northern edge of the base.

Training Installation Access

Access to Camp Navajo is regulated by Arizona State employees. Due to the restrictions necessary for security of the installation's training and ordnance storage missions, there is a slight increase to the cost of locating the power plant site on Camp Navajo, as opposed to the nearby Bellemont area. The scope of authorizing and verifying access for all third party personnel who require access to the site would tax the current base security to the point of requiring more full-time personnel, and potential improvements to the security checkpoints and fencing.

Considering access to the 200 Area (as it has been identified as the most likely on-installation location), it is located very close to the base perimeter access road, and the cost of developing a construction access lane may be justified as an alternative to improving the existing installation entry portal to handle the additional traffic.

Water Availability and Discharge

Water Sources, Distribution and Uses

Camp Navajo currently has two major sources of raw water: several shallow wells at approximately 300 foot depth, and one deep well at approximately 2,000 foot depth. The shallow wells tap into a perched aquifer; these shallow wells vary seasonally from an average total production of 80 gallons per minute (GPM), up to a maximum of 200 GPM. The deep well is capable of 70 to 80 GPM, but it is significantly more expensive to pump due to the depth of the well. The water from the shallow wells typically does not require heavy treatment, having low total dissolved solids and low to moderate turbidity, which varies seasonally. The addition of an onsite power generation plant would provide water security by powering the deep well in the event of a grid failure, and seasonal lows of the shallow wells.

These sources of water feed a network of water lines and fire hydrants that run throughout the installation. Due to the age of this infrastructure, certain areas have developed leaks. As a result, Camp Navajo facilities management has recently installed new water lines, in the 200 Area. This is significant because the ground throughout most of the installation is very rocky, which forces trenching costs to be at least $100/foot and routing to be unpredictable.

The water distribution network includes three major storage units: a 1,000,000 gallon fire tank, a 250,000 gallon clear well, and a 500,000 gallon water tower, kept level for distribution pressure throughout the installation. Facilities managers reported being able to maintain the level of the fire tank while it was experiencing a 150,000 gallons per day (GPD) draw for a period of approximately one week.

Water use varies heavily depending on the number of personnel on base. These influxes of personnel (typically during summer months), which can cause demand to exceed the system's capability, paired with the seasonal variations of water availability from the shallow wells, create very unpredictable availability of water onsite. The proposed power plant would take second priority to the base's other missions of training and ordnance storage.

Wastewater Treatment

Camp Navajo has a wastewater treatment plant which is permitted to operate at a capacity of 60,000 GPD. Monthly averages of plant throughput from 2017 show the plant to be well below this limit, with the highest monthly average being 42,560 GPD. The daily maximum does exceed this limit at times due to infiltration of the wastewater pipes from groundwater. Actual production from the installation without counting seasonal water infiltration is between 30,000 GPD and 45,000 GPD when at or near capacity of Soldiers onsite.

Community Acceptance

In the recent past, land use planning activities by Camp Navajo (i.e. their 2017 Installation Master Plan) have mentioned biomass energy development as a potential use on the installation. Although the discussion of bioenergy development on the installation was relatively brief, the securing of funds by the AZDEMA to conduct a biomass energy feasibility study indicates that the base is definitely interested in a locally sited biomass energy facility, whether located on the installation or nearby.

TSS Consultants (TSS) interviewed both Camp Navajo and Coconino County officials regarding potential public acceptance of a biomass energy facility in the Bellemont/Camp Navajo area. Coconino County officials indicated they are currently updating the Bellemont Area Plan, which was last prepared in 1985. Although these updates have yet to discuss the potential for siting a biomass power plant in the Bellemont area, the officials opined that a biomass power plant was permittable in the Bellemont area industrial zoned property (see Figure 7 above).[5]

Coconino County has prepared a comprehensive land use plan for the County that has been vetted through a thorough public review. The Coconino County Comprehensive Plan (adopted by the Coconino County Board of Supervisors in December 2016) encourages biomass energy development. In the Energy section of the Plan, Policy Number 25 states:

> *"The County supports biomass energy production through the distribution of forest thinning materials to residents for firewood and for use by utility-scale*

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[5] Personal communication with Matt Ryan, Coconino County Supervisor, and Jay Christelman, Director, Coconino County Community Development Department.

facilities if the impacts of these facilities on the public health, wildlife, air quality, and the natural environment of the nearby communities can be avoided, minimized, or mitigated."

Coconino County further encourages biomass energy, with certain caveats, in its Energy Element adopted by the Board of Supervisors on July 10, 2012 (Appendix D of the Plan). Goals and policies relevant to siting a biomass energy facility are posted below:

Goal: Support the development of clean biomass energy.

Policies: The development of biomass energy facilities is supported if impacts on the nearby communities, wildlife, air quality, and the natural environment can be avoided, minimized, or mitigated.

The County supports biomass energy through the distribution of forest thinning materials to residents for firewood and utility facilities.

Studies to demonstrate the impacts on public health and air quality are important in the approval of utility-scale biomass energy projects and should be developed in coordination with expert entities.

The County shall be stringent concerning air pollution, view sheds, clear skies, collection methods, land disturbance, and emissions when considering utility-scale projects.

Discussion with AZDEMA staff also revealed the potential public acceptance of a biomass power plant on the installation itself. This possibility was addressed in the Camp Navajo IMP and suggested the energy facility should be located at the 200 Area, as this area is proposed to be further developed for commercial and industrial operations.

Financial Performance

The financial performance of this proposed biomass power plant is still missing essential components for a high-level analysis. The information available so far indicates the potential for positive economic operation of a biomass power facility in the presence of a sufficient power sales rate. A recent study performed by Black and Veatch[6] for Arizona Public Service (APS) found the costs of the renewable energy to be in excess of $190/MWh due to several factors, not least among which that the additional renewable power did not qualify for the existing renewable power standard monetization which subsidized the higher cost of biomass energy compared to other sources. APS already has an excess of the required renewable energy in their portfolio; therefore, APS sees no financial benefit from the renewable power.

Preliminary estimates show the delivered cost of wood to the Camp Navajo site in the quantities necessary require at least $50/MWh to cover the fuel cost. Additional to this cost is the operation and maintenance costs, financing costs, wages and parasitic load of the plant's motors associated with the continuous operation of the facility. When added together, these costs will require a power sales agreement ranging between $122.5/MWh and $137.30/MWh. Note that

[6] APS Forest Bioenergy Report, November 2017.

more detailed analysis and findings are presented in the Economic and Financial Analysis section.

Societal Benefits

A robust and expanding bioenergy market sector in Arizona provides a number of compelling societal benefits, some of which are in addition to typical benefits of other renewable energy technologies.[7]

- **Promotes healthy forests and defensible communities.** Provides a ready market value for woody biomass material generated as a byproduct of forest management, hazardous fuels reduction and forest restoration activities.[8] This helps encourage projects that contribute to defensible communities and healthy forest ecosystems through the generation of income to fund additional treatment activities.

- **Protects key watersheds.** A significant portion of the state's water resources flow from forested landscapes. Healthy forest ecosystems in these upland watersheds ensure that sustainable quantities of high-quality water for both domestic and agricultural uses will continue to flow.[9,10,11,12] This is particularly important given the arid nature of Arizona's climate and the predicted effects of climate change on future water production and the ability of forest management projects to protect and enhance both quality and quantity of water from forested landscapes. Increased water yield of 9-16%[13] could result should additional forest acres be thinned within a watershed (from experience in the Sierra Nevada range).

- **Provides net air quality and greenhouse gas benefits.** Forest biomass material that would otherwise be disposed of by burning in open piles, in prescribed broadcast burns, or would have been consumed in a wildfire, can be utilized in a controlled manner to provide renewable energy (energy conversion units including boilers and gasifiers that are equipped with Best Available Control Technology), thus reducing air emissions and improving regional air quality. The air quality benefits are significant, with 95-99% reduction in particulate matter, carbon monoxide, and volatile organics, and a 60-80%

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[7] C. Mason, B. Lippke, K. Zobrist et al., "Investments in Fuel Removals to Avoid Forest Fires Results in Substantial Benefits," Journal of Forestry, January/February 2001, pp. 27-31.
[8] M. North, P. Stine, K. O'Hara, W. Zielinski, and S. Stephens, "An Ecosystem Management Strategy for Sierran Mixed-conifer Forests," USDA Forest Service, PSW General Technical Report PSW-GTR-220, 2009.
[9] D.G. Neary, K.C. Ryan and L.F. DeBano (eds.), Wildland Fire in Ecosystems: Effects of Fire on Soils and Water, Gen. Tech. Rep. RMRS-GTR-42-vol 4. Ogden, UT, USDA Forest Service Rocky Mountain Research Station, 2005.
[10] R.R. Harris and P.H. Cafferata, Effects of Forest Fragmentation on Water Quantity and Quality. Paper presented to the Conference on California Forest Futures, Sacramento, CA, May 23-24, 2005.
[11] J.D. Murphy, D.W. Johnson, W.W. Miller, R.F. Walker, E.F. Carrol, and R.R. Blank, "Wildfire Effects on Soil Nutrients and Leaching in a Tahoe Basin Watershed," Journal of Environmental Quality, Volume 35, 2006, pp. 479-489.
[12] Numerous studies led by Lee H. MacDonald, Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship.
[13] R.C. Bales, et al., "Forests and Water in the Sierra Nevada: Sierra Nevada Watershed Ecosystem Enhancement Project," November 2011.

reduction in nitrogen oxides when compared to open burning.[14,15,16] An additional climate change benefit results from replacing fossil fuel fired power generation with renewable bioenergy.

- **Provides economic development and employment.** Most bioenergy facilities are sited in rural areas that have limited economic development opportunities. Commercial-scale bioenergy facility jobs include plant operations and maintenance as well as fuel collection, processing and transport. Approximately five jobs are created per MW of bioenergy generation.[17]

- **Reduces waste going to landfills**. Wood waste destined for landfills can be recovered and utilized, thus extending the service life of landfills and reducing the need to develop additional landfill facilities while producing renewable energy and reducing greenhouse gases.

- **Delivers distributed, baseload generation**. Locating new, commercial-scale bioenergy facilities strategically across forested regions in Arizona may mitigate the need for transmission/distribution system upgrades, as relatively small generation facilities (15 to 30 MW) require relatively little transmission capacity to deliver power to load centers. This will also provide strategic 24/7 baseload generation in regions that are remote and prone to inconsistent power availability.

- **Protects transmission/distribution infrastructure.** Power distribution infrastructure in Arizona is significant. Many of the state's generation assets utilize transmission and distribution systems located in forested regions to deliver generation to load centers. Forest management and hazard reduction projects can reduce the likelihood of wildfire damage to valuable power distribution infrastructure. It can also minimize the potential for power distribution infrastructure causing large-scale wildfire events.

- **Utilizes renewable and sustainable feedstocks.** Bioenergy facilities are sized appropriately to utilize biomass from sources that continue to produce biomass in a long-term, sustainable way.

- **Reduces wildfire suppression costs.** Forest management fuel reduction activities can significantly reduce the economic costs for fighting wildfires. See detailed discussion in the Impact Analysis section.

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[14] Bruce Springsteen, Tom Christofk, Steve Eubanks, Tad Mason, Chris Clavin, and Brett Storey, "Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning," Journal of the Air and Waste Management Association, Volume 61, January 2011, pp. 63-68.

[15] Greg Jones, Dan Loeffler, David Calkin, and Woodam Chung, "Forest Treatment Residues for Thermal Energy Compared With Disposal by Onsite Burning: Emissions and Energy Return," Biomass and Bioenergy, Volume 34, 2010, pp. 737-746.

[16] Carrie Lee, Pete Erickson, Michael Lazarus, and Gordon Smith, "Greenhouse Gas and Air Pollutant Emissions of Alternatives for Woody Biomass Residues," prepared by the Stockholm Environment Institute for the Olympic Region Clean Air Agency, November 2010.

[17] G. Morris, The Value of the Benefits of US Biomass Power, November, 1999, NREL Publication SR 570-27541.

Findings

Preferred Site Location

Both of the Bellemont industrially zoned properties located between the northern border of Camp Navajo and I-40 and the 200 Area appear to be appropriate sites for a commercial-scale bioenergy facility. Both sites have adequate space for the energy facility and accompanying feedstock storage. Additionally, the ability of the biomass power plant to store long-term supplies of fuel (average of three month usage inventory) drastically improves the installation's energy and water security by providing heat and power to cover all current Camp Navajo needs. If located on Camp Navajo, the revenue generated by the facility would also provide an influx of capital via the water supply contract and wastewater treatment contract formed between the owner/operator of the plant and AZDEMA to improve on-base freshwater and wastewater infrastructure.

For wood chip trucks to adequately access these two sites, it is recommended that the Coconino JLUS planning work continue to encourage and work with ADOT and stakeholders in support of the expansion of the I-40 overpass (Exit 185).

Fuel Sourcing Area Boundaries

Considering the relatively active land management activities in the region (including the Four Forest Restoration Initiative), a 50-mile radius FSA should provide adequate volumes of forest and grassland restoration byproducts to sustain a commercial-scale bioenergy facility.

CAMP NAVAJO ENERGY DEMAND INCENTIVES AND PERMITTING

Electrical and natural gas usage data for the past three years was reviewed for the Camp Navajo site. In general, the data shows a maximum instantaneous usage of approximately 10 million British thermal units[18] per hour (MMBtu/hour) of natural gas and maximum electrical demand charge of 1.95 megawatts[19] (MW). This data is sufficient to establish the sizing criteria. The peak usage of natural gas is below the capacity of the natural gas supply line, which is a four inch pipe, capable of approximately 13-15 MMBtu/hour of maximum gas delivery.

To use heat from the power plant, modification or replacement of the current natural gas and electric heaters throughout the camp would be necessary. Also needed would be a condensate collection and return system, and a network of piping to deliver heat from the 200 Area to the main complex of buildings. At least 7,300 feet of piping would be necessary to deliver heat to the boundary of each building, and distribution piping within each building would be necessary to convert each air handler or hot water heater. The heating system used when the camp was established in 1944 was a central system, but this system covers fewer than half of the current buildings. This original heating system has also been abandoned for more than 10 years, so it is likely to require significant repair or replacement to be returned to service.

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[18] Btu = energy required to raise the temperature of one pound of water by one degree Fahrenheit.
[19] MW = one million watts of electrical power.

Heat Load

Analysis of the data shows an annual natural gas cost between $155,000 and $184,000/year. The monthly natural gas purchasing data was analyzed using typical usage patterns for heating systems, and the system's maximum demand was estimated. This maximum instantaneous use occurs typically in the month of January and peaks at 8.9 MMBtu/hour.

The payback for offsetting these gas purchases must be evaluated against the energy cost of heat from the power plant. Essentially about half of this annual expense represents the expected potential savings of replacing natural gas used for heating and domestic hot water with steam or hydronic heat[20] from the proposed biomass power plant.

Findings

The conclusions from analysis of the heat load is the peak use of natural gas on Camp Navajo is less than 10 MMBtu/hour, and much lower on an annual basis. The heating systems for the buildings on the camp are distributed in nature, making a full conversion to a district heating system necessary for all building heating, ventilation and air conditioning (HVAC) systems, which is not economically feasible.

Electrical Load

Electrical usage at Camp Navajo is variable, with significant decreases and increases over the three year period reported. These fluctuations make the annual electrical energy usage estimates less accurate for any given month or year in the future. Additionally, the maximum electricity used does not follow a seasonal pattern. The electrical instantaneous demand can vary from 257 kW to 1,947 kW; additionally, there is no easy way to separate the amount of electricity used for heating and non-heating uses. This trend follows typical utility use on the installation which rise and fall based upon the number of people onsite. Economic payback models must use conservative values in estimating future savings which, in this case, means the average annual electrical cost of $275,000/year would be the basis for any model. This significantly limits the payback of such a proposed modification to installation infrastructure.

Summertime loads could see an increase of electricity usage from air conditioning, which is currently deployed in most base buildings. It is possible to leverage the heat from the power plant for a district cooling system using an absorption chiller. Sizing of the cooling load would have to be performed to estimate its full cost. Given the number of buildings, if a chilled water system is installed, it would likely require several dedicated chilled water loops.

Findings

Analysis of the electrical load at Camp Navajo showed a sporadic usage profile that varied anywhere from 250 to 1,900 kilowatts[21] (kW), with high variability month to month. The average electrical usage for the last three years was 4,566 MWh, varying as much as 44% from

[20] Hydronics is the use of a liquid heat transfer medium in heating systems. The working fluid is typically water, glycol or mineral oil.
[21] kW = one thousand watts of electrical power.

the average above and below, year to year. The average continuous electrical use was 0.52 MWh which, offset by a biomass electric plant, represents an annual cost of $471,091. If AZDEMA were to purchase electricity directly from this plant, depending on which arrangement was constructed, it could reduce this cost by $74,000 (at $86.97/MWh) or increase it by $61,500 (at $116.65/MWh).

Electrical Distribution Infrastructure

Camp Navajo has a single substation (owned by APS) which supplies its electricity. This substation operates at 12.5 kV, and the capacity is currently more than the installation's usage of electricity. If a 20 to 30 MW biomass power plant were located onsite, a new substation to transform the additional current for the electrical tie in would be necessary. Preliminary discussion with APS[22] confirmed the high voltage transmission lines just north of the installation have the capacity to transmit extra electricity (up to 30 MW), but a system impact study would be required to confirm how the additional power fits within the APS transmission/distribution system for the area.

Figure 9. Image of 12.5 kV Substation

Source: TSS Consultants

Findings

The supply of 12.5 kV electricity to the 200 Area would have to be increased to site a 20 to 40 MW power plant. If an industrial campus were added as well, this significantly increases the amount of electrical service necessary. This tie-in to the grid would require an in-depth system impact study by APS to determine electrical transmission/distribution capabilities in the area.

[22] Brian Wallace, APS.

Economic Review

Camp Heating from Power Plant

The costs and paybacks to use steam or hydronic heating from the power plant to satisfy the installation's current energy needs was evaluated. The cost estimate to trench the steam or hot water delivery pipe from the 200 Area to the garrison headquarters and surrounding infrastructure (Areas A through F in Figure 4) is approximately $700,000, indicating this conversion would not have an acceptable payback for the capital expenditure required. The estimate of running steam piping, condensate collection, addition of heating coils to air handlers throughout the facility and other infrastructure required to utilize the heat results in an installed cost of approximately $2,450,000. This estimate assumes energy sales for the power plant of $166,000 per year, providing a simple payback of 15 years, not including interest.

District Heat System from Power Plant

The biggest potential for additional plant income is steam/heat sales to other businesses located in the immediate vicinity of the power plant (200 Area or Bellemont industrial area). The economic incentive for the other businesses depends on the cost differential of heat from the biomass power plant vs alternative sources of energy, primarily natural gas. The current cost of natural gas onsite is approximately $7.97/MMBtu per the Camp Navajo cost data. This is slightly lower than the current commercial rate for natural gas per the U.S. Energy Information Administration for 2018.[23]

The current natural gas delivery infrastructure to the site would require upsizing to supply any significant increase in continuous demand, essentially upgrading the service from commercial-scale to industrial-scale. If that improvement were made, industrial natural gas rates are discounted over commercial rates due to economies of scale. The industrial cost of natural gas in Arizona has ranged between $6.56 and $7.11 in the last six months.[24] If the 200 Area were converted to an industrial campus, industrial supply of natural gas would most certainly be a required infrastructure improvement, even if the biomass power plant were the main energy supplier.

The biomass power plant would be able to supply steam for approximately the cost of the biomass fuel. Assuming a delivered biomass fuel cost of $40/bone dry ton (assuming typical efficiencies of gas and biomass boilers), the biomass derived heat in this case would save approximately $4.46/MMBtu, providing a strong incentive to use processed steam or waste heat from the biomass power plant. The exact economics of this would have to be confirmed once the final design and engineering of the biomass power plant is completed. To demonstrate the economic incentive, if an industrial user (a moderately sized lumber mill) required 30,000 lb./hour of steam for 8,000 hours/year, natural gas would cost $2,000,500 and wood energy would cost $930,900, resulting in a savings of approximately $1,070,000/year in energy costs.

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[23] US EIA. (2018). *Natural Gas Prices Commercial* [N3020AZ3m.xls]. Available from US EIA Web site: https://www.eia.gov/dnav/ng/hist/n3020az3m.htm.
[24] US EIA. (2018). *Natural Gas Prices Industrial* [N3035AZ3m.xls]. Available from US EIA Web site: https://www.eia.gov/dnav/ng/hist/n3035az3m.htm.

Subsidies, Incentives and Credits

Northern Arizona Forest Fund

The Salt River Project (SRP) and the National Forest Foundation sponsor the Northern Arizona Forest Fund (NAFF). This fund provides funding support for removal of invasive juniper vegetation encroaching on natural grasslands within the Salt and Verde River watersheds. These watersheds are located west and south of Camp Navajo (within the Camp Navajo Fuel Sourcing Area). Currently SRP is partnered with Novo Biopower to supply renewable energy for their portfolio. Novo Biopower is currently receiving biomass material from both forest and grassland improvement projects. Funding from the NAFF could be available to support forest and grassland improvement projects adjacent to Camp Navajo.

Renewable Energy Production Tax Credit

Federal Renewable Energy Production Tax Credit (PTC) provides a corporate tax credit of $0.012/kWh ($12/MWh) for open loop biomass for the initial 10 years of operation. The program is currently expired but has been renewed five times since it was first implemented in 1992. It is likely to be renewed again due to the program's success in expanding the country's renewable energy infrastructure; however, its future is unpredictable due to the current political climate. This would represent approximately $2,040,000/year in federal tax credits and $20 million over the 10-year life of the credit, if reenacted.[25]

Renewable Energy Certificates

Renewable Energy Certificates (RECs) are an accounting tool, which represents one MWh of electricity that was generated at a renewable source (e.g., wind, solar, biomass, geothermal, etc.). There is no one entity which regulates RECs nor a universal standard that defines the value. They are a tradeable commodity, that carry value on the open market for entities (typically energy users) who wish to purchase certificates that qualify as a renewable energy credit. A total of 36 states and territories recognize that RECs can be used to track and transact renewable electricity on the grid.[26] Each state may call them something different, but ultimately they are a tracking mechanism for renewable energy because it is not physically possible to assure electricity generated at a particular generating station is sold to a particular end user. A biomass power plant at Camp Navajo could participate in the voluntary REC market. The National Renewable Energy Lab (NREL) green power pricing program[27] reports REC values; an average of $0.0153/kWh for the state of Arizona and neighboring states was calculated. The sale of the RECs generated by the facility could bring as much as $3,900,000/year, if a buyer for the entire plant capacity were secured at the average rate.[28]

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[25] Assumes biomass power plant scaled at 20 MW of net output and 8,500 capacity-hrs/yr.
[26] Jones, Todd, Robin Quarrier & Maya Kelty. Center for Resource Solutions. *The Legal Basis For Renewable Energy Certificates*. Pg. 3. http://resource-solutions.org/wp-content/uploads/2015/07/The-Legal-Basis-for-RECs.pdf.
[27] https://www.nrel.gov/analysis/assets/docs/utility-green-pricing-program-list.xlsx, Neighboring states include California, Colorado, Nevada, New Mexico and Utah.
28 Assumes biomass power plant scaled at 30 MW of net output and 8,500 capacity-hrs/yr.

Emission Reduction Credits

Emission Reduction Credits (ERCs) are similar to RECs, but instead of quantifying renewable energy production, ERCs recognize reduction of criteria pollutants, precursor pollutants or greenhouse gas emissions identified in the federal Clean Air Act. ERCs are deposited into an emissions bank established to encourage net improvements in air quality. Such banks may be formal or informal.[29] The Arizona Department of Environmental Quality is authorized to maintain the Emissions Bank for the state[30] on a volunteer basis. Current Rules 204 and 242 in Maricopa County are written to require any ERCs generated to be from facilities located in non-attainment areas, which means an area where ambient levels of pollutants are higher than the National Ambient Air Quality Standards (NAAQS). Coconino and Yavapai counties have never been identified, in whole or in part, as non-attainment areas per the US EPA air quality Green Book's Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants.[31] However, the passage of House Bill 2152 amending section 49-410 states that any state subdivision or person may apply for ERCs by reducing qualifying emissions. Only the reduction of existing emissions may be claimed, which at Camp Navajo would come from natural gas. The number of credits available, even assuming a full reduction of natural gas use at the installation, is insignificant in terms of the net costs of a 20 to 30 MW power plant.

Enterprise Zone – Coconino County

Enterprise zones[32] are administered by the Arizona Department of Revenue. Coconino County assembled a general information flier regarding enterprise zones to guide small businesses to apply for either the Income/Premium Tax Credits or the Property Tax Reductions. A power plant would not qualify for the Income Tax Credit, due to the eligibility requirement of no more than 10% retail sales at the zone location. The Property Tax Reduction may be eligible if a special ruling were made to classify the company which owns the power plant as a manufacturer, and the company had less than 100 employees. This petition would have a low chance of approval unless the review board at the Arizona Department of Revenue was liberal with the interpretation of the definition of manufacturer to include power plants. A case could be made for the petition to qualify the power plant for this beneficial tax rate of 5%.

Findings

There are several economic incentives that have the potential to improve the financial viability of a biomass power plant, mostly benefitting the year-to-year operations and maintenance (O&M) cost of the facility. Fuel supply costs could be reduced by utilizing funding from community based organizations (such as NAFF) to support forest and PJ grassland restoration, and up to $3 to 3.9 million dollars/year could be available from either the PTC or the sale of RECs.

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[29] USDA, Natural Resource Conservation Service. *Emission Reduction Credits As An Incentive To Voluntary Compliance.* Washington D.C.

[30] Per Arizona Revised Statute (A.R.S.) section 49.410

[31] EPA. Green Book: Arizona Nonattainment/Maintenance Status for Each County by Year for All Criteria Pollutants. https://www3.epa.gov/airquality/greenbook/anayo_az.html. August 31, 2018. Washington D.C.

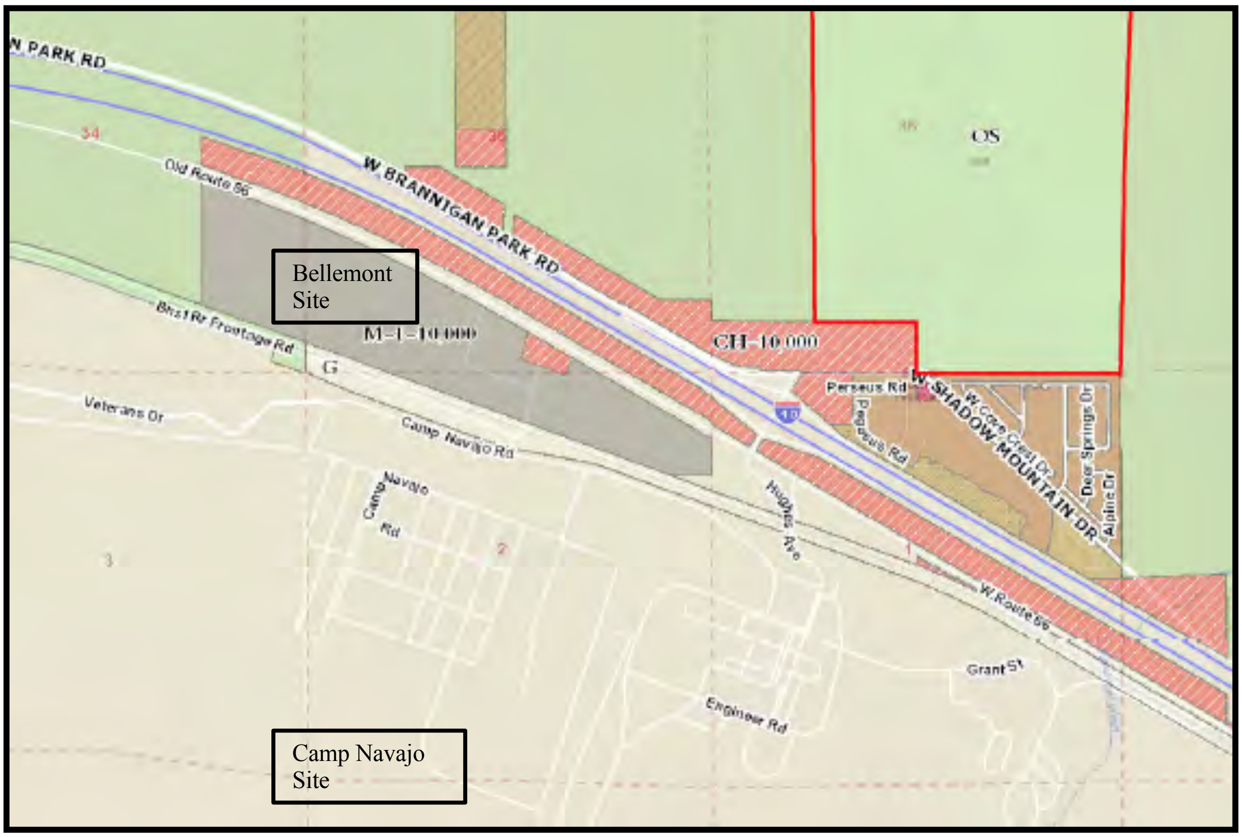
[32] Enterprise zones are geographic areas targeted by a government authority for special tax or regulatory exemptions in order to promote local economic development.

Environmental Permitting

Site Descriptions

The Site Conditions Analysis identified the potential for siting a 20 to 30 MW biomass-fired power plant at two locations in the Bellemont-Camp Navajo area. The Camp Navajo site is located in the 200 Area, and the Bellemont site is on Coconino County industrially zoned property situated between I-40 and the northern boundary of Camp Navajo. These sites are indicated in Figure 10.

Figure 10. Approximate Location of Potential Biomass Power Plant



The Bellemont site is located approximately 12 miles west of Flagstaff, directly south of I-40. It is a vacant, grassland/sagebrush area adjacent to ponderosa pine forestlands. It is a slightly easterly sloping site and is relatively flat (see Figure 11).

To the south of the Bellemont site is the Camp Navajo site which is located on the southern edge of the 200 Area (see Figure 12). Between the Bellemont and Camp Navajo sites are the Burlington Northern Santa Fe railroad tracks. These tracks are a major east-west route with up to 100 trains passing through this area every day.

Figure 11. Potential Biomass Power Plant Site in Bellemont

Source: TSS Consultants

Figure 12. Potential Biomass Power Plant Site at Camp Navajo (Area 200)

Source: TSS Consultants

General Power Plant Features

A proposed 20 to 30 MW biomass power plant would consist of biomass-fired boilers fueled by forest residues, producing steam to run electrical generation equipment. Dry cooling towers would be utilized to minimize water needs, as well as wastewater discharge. For air emissions control, the plant would be designed with Best Available Control Technology (BACT) for emissions such as oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter (PM). BACT implies the most stringent emission control technique, which has been achieved in practice and is commercially available.

Principal Regulatory Agency Involvement

The principal regulatory agencies that would be involved with the environmental review process include:

- Arizona Department of Environmental Quality, Air Quality Division (air emissions)
- Arizona Department of Environmental Quality, Water Quality Division (storm water and wastewater)
- Coconino County Department of Community Development (land use for the Bellemont site)

Air Quality Standards

Air quality in the region (Coconino County) can be considered good. In regards to exceeding federal or state air quality standards, Coconino County had no exceedances for ozone, carbon monoxide, PM10 (particulate matter 10 microns or less in size) or ozone in 2016 or 2017.[33] It did meet the federal exceedance threshold of 0.07 parts per million (PPM) in 2015.[34] According to Arizona Department of Environmental Quality (ADEQ), Air Quality Division maps, the project area is in attainment of federal and state air quality standards for ozone, PM10, SOx, and carbon monoxide (CO). The closest non-attainment area is Maricopa County for ozone, approximately 86 miles to the south of the Bellemont-Camp Navajo area.

Visibility, as an air quality issue, is of paramount concern in northern Arizona, principally due to the scenic amenities of the region (e.g., Grand Canyon National Park). There are several areas in the region designated by the U.S. Environmental Protection Agency (US EPA) as Class I visibility areas. Such an area is provided extra protection by the US EPA in regards to visibility and scenic view shed impairment. The proposed project is located approximately 15 miles north from the nearest federally designated Class I area (Sycamore Canyon Wilderness Area).[35] This will require that during the air quality permitting activities, additional modeling and evaluation will be necessary to determine if there will be any impact to this Class I area.

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[33] 2017 Arizona Department of Environmental Quality Annual Report, http://static.azdeq.gov/aqd/air_report2017.pdf

[34] Ibid

[35] https://www.epa.gov/visibility/list-areas-protected-regional-haze-program

The proposed biomass power plant would be designed with BACT for NOx, SOx, and PM. The NOx emission control system would be an ammonia injection system, with limestone injection for any necessary SOx control. PM would be controlled via a bag-house or electro-static precipitator (ESP).

Using data from a similar facility, estimated controlled emissions for a 20 to 30 MW biomass power plant could be: NOx, 102.8 to 151.5 tons/year; SOx, 45.6 to 67.2 tons/year; PM, 22.8 to 33.62 tons/year; CO, 102.8 to 151.5 tons/year; VOCs; 22.8 to 33.62 tons/year. It is estimated that the energy output for the biomass power plant would be approximately 270 to 405 MMBtu/hour with an annual operating capacity of approximately 95% (8,300 hours/year).

Based on these emissions and energy input, an air quality permit is required by the ADEQ Air Quality Division for either site. Based on the estimated emissions for the plant, it does appear that the facility would require a Class I permit. In order to qualify for a Class I permit, the facility would have to have the potential to emit 100 tons/year (or more) of one of the air pollutants listed above.[36] This level of pollutants would also designate a facility as a "major stationary source." Some of the pollutants exceed 100 tons/year (NOx and CO), thus a Class I permit is necessary to operate the facility at 95% annual capacity. In addition, a new major stationary source of air pollution must obtain its air quality control permit before starting construction. However, for the proposed project, (even if 30 MW does exceed the 100 tons/year of any applicable pollutant) a Prevention of Significant Deterioration (PSD) review, is not required for the permitting process.

If operating as a major source, the facility would also be required to obtain a Title V permit. This Title V permit would be issued by the ADEQ, as it is approved by the US EPA for issuing and enforcing the Title V permit.

It should be noted that Camp Navajo already maintains a Class II air quality permit from the ADEQ (Permit no. 65288). This permit is principally for the numerous natural gas-fired space and water heating systems on the installation.

Wastewater Standards

To reduce water consumption, the proposed power plant would utilize an air-cooled condenser. Potential wastewater discharge from an air-cooled 20 to 30 MW range plant is estimated to be in the 16 to 24 GPM range. If this amount is not reduced prior to discharge, this would result in approximately 23,000 to 35,500 GPD, which would likely have to be discharged to a lined impoundment at the Bellemont or Camp Navajo sites and subjected to ambient evapotranspiration for ultimate disposal (i.e. evaporation). This impoundment would need to be very large to handle full wastewater discharge. In addition, evapotranspiration would be very limited in the winter, thus requiring several acres of lined impoundments. A percolation pond

[36] Class I permits are issued to any source that meets the requirements of A.A.C. Title 18, Chapter 2, Article 302(B)(1). Such sources include: Any Major Source – A "major" source as defined by the A.A.C. Title 18, Chapter 2, Article 101(64) is any source that has the potential to emit 100 tons per year of any criteria air pollutant. A source is also considered major if it has the potential to emit 10 tons per year of any single Hazardous Air Pollutant or 25 tons per year of any combination of Hazardous Air Pollutants.

would most likely not be permittable due to shallow, and heavily used, groundwater aquifer. In addition, percolation rates are extremely slow in the Bellemont/Camp Navajo area. Thus, in designing the wastewater handling system, a "zero-discharge" approach might be necessary. Such an approach would utilize a reverse osmosis system or a power evaporation unit to minimize wastewater as much as possible. Both systems would increase the parasitic load of the power generation facility.

If lined impoundments are to be used for the project, a water quality permit will have to be obtained from the ADEQ Water Quality Division. Fortunately, the Division has instituted a general permitting program, which makes such permitting relatively streamlined.

At the Camp Navajo site, there is a permitted wastewater treatment plant (WWTP) on the base (ADEQ Permit No. P-101528). However, its design capacity is currently only 60,000 GPD. Wastewater from the proposed 20 to 30 MW facility would likely overwhelm this WWTP during peak periods of activities on the installation. A lined impoundment for just the biomass power plant may be warranted. Permitting for this impoundment would be the same as for the Bellemont site as well as storm water permitting.

Storm Water

A 20 to 30 MW biomass power plant as a direct combustion steam cycle system, along with a wood chip feedstock storage yard, would require preparation of both a construction phase Storm Water Pollution Prevention Plan (SWPPP) and operational SWPPP at either site.[37] These SWPPPs would allow construction of the biomass facility to file for a Notice of Intent (NOI) under the Arizona Discharge Elimination System (AZDES) Storm Water Construction General Permit. It will also allow for the submittal of an NOI for the AZDES Industrial Storm Water Permit (non-mining).

Land Use and Zoning

Regarding the Bellemont site, the Coconino County Community Development Department has designated the general Bellemont area as a Planned Community (PC) Zone. As per the most recent zoning map, the proposed project site is zoned M-1-10, 000 Light Industrial. Per Section 12.0 of the Coconino County Zoning Ordinance, this zone is *"intended for light industrial and limited service commercial uses that can meet high performance standards but that frequently do not meet site development standards appropriate to planned research and development of industrial parks."* However, this zone does allow, per Section 12.1, electrical generating stations and substations provided such facility apply for and receive a Conditional Use Permit (CUP) from Coconino County. Discussions with Coconino County confirm that a biomass power plant could be constructed and operated on the site provided the proposed facility obtains a CUP.[38]

In order to obtain a CUP, in addition to a relatively standard application submittal, Section 5.3 of the Coconino County Zoning Ordinance requires that a citizen participation plan be prepared and implemented. Tenets of this plan require that the CUP applicant contact neighbors and other

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[37] Steam electric power generating facilities are required by federal law to acquire storm water permits (40 CFR 122.26(b)(14)(i)-(xi)).

[38] Personal communication with Matt Ryan, County Supervisor, District 3, and Jay Castelman, Coconino County Community Development Director, August 21, 2018.

potentially affected property owners in the proposed project vicinity and inform them about the project and solicit their input regarding the project. Prior to the submittal of the CUP application, prospective applicants must conduct a neighborhood community meeting. The scope and breadth of the citizen participation plan is determined by the applicant, but after consultation with the Coconino County Community Development.

Another land use related concern raised by the Community Development staff was adherence by the proposed project to County Zoning Ordinance Section 17, and specifically Section 17.4 – Establishment of Astronomical Zones. Due to various astronomical telescopes located in Coconino County, such as those at the Naval Observatory, Flagstaff Station (NOFS), there are three distinct zones in the county, which dictate the use of outdoor lighting at a facility. The proposed power plant is in the least restrictive zone (Zone III); however, due to the importance of the DoD mission of NOFS, further analysis of the impacts to the Observatory from a commercial-scale bioenergy facility at Camp Navajo would be necessary.[39]

Regarding land use entitlement on Camp Navajo, the land uses on the installation are guided by the 2017 Camp Navajo Installation Master Plan which includes an Area Development Plan (ADP). The ADP includes regulating plans for Camp Navajo that establish development regulations for respective areas on the installation. The ADP infers that commercial-scale power generation in Area 200 is an acceptable land use. Coconino County has no jurisdiction on land use within the boundaries of Camp Navajo.

Findings

The Bellemont industrial-zoned site and the Camp Navajo 200 Area site both appear to be permittable and any environmental impacts, such as air quality and water impacts, can be mitigated in a manner that are acceptable to the regulatory agencies, citizens, communities and other stakeholders. While the 200 Area appears to be the optimal site at Camp Navajo, there are other sites on the base where a commercial-scale bioenergy facility could be sited.

BIOMASS FEEDSTOCK SUPPLY AVAILABILITY AND COST

Key to understanding the potential opportunity to site a wood-to-energy facility at or near Camp Navajo is confirmation of a sustainably available woody biomass material supply from within economic haul distance (50-mile radius). The 50-mile radius FSA was selected as a result of interviews with forest managers familiar with forest resource supply availability and demand in the region. In addition, TSS has significant experience within northern Arizona and findings from previous resource assessments[40] align with selection of 50-mile radius as the optimized scale for the Camp Navajo FSA. In addition, from TSS' previous work in northern Arizona, three primary sources of woody biomass material were selected as potential feedstock sources for this analysis.

[39] Per discussions with Colonel Garcia, Garrison Commander, Camp Navajo.

[40] 2002 study for the Greater Flagstaff Forest Partnership, 2005 study for the Tusayan-Grand Canyon Sustainable Energy Project Committee, 2013 study for Northern Arizona University, 2017 + 2018 studies for the Upper Verde River Watershed Protection Coalition.

Forest Feedstock

- Timber harvest residuals (limbs, tops).
- Forest fuels reduction and forest restoration (small stems removed to mitigate wildfire behavior and return forest landscapes to more natural stocking conditions).
- Sawmill residuals (sawdust, bark, chips, shavings).

Urban Wood Waste

- Wood waste generated onsite at Camp Navajo (crates, dunnage, construction and demolition wood).
- Wood waste generated in urban centers (e.g., Williams, Flagstaff) that could be utilized as biomass feedstock (tree trimmings, construction and demolition wood).

Grassland Restoration

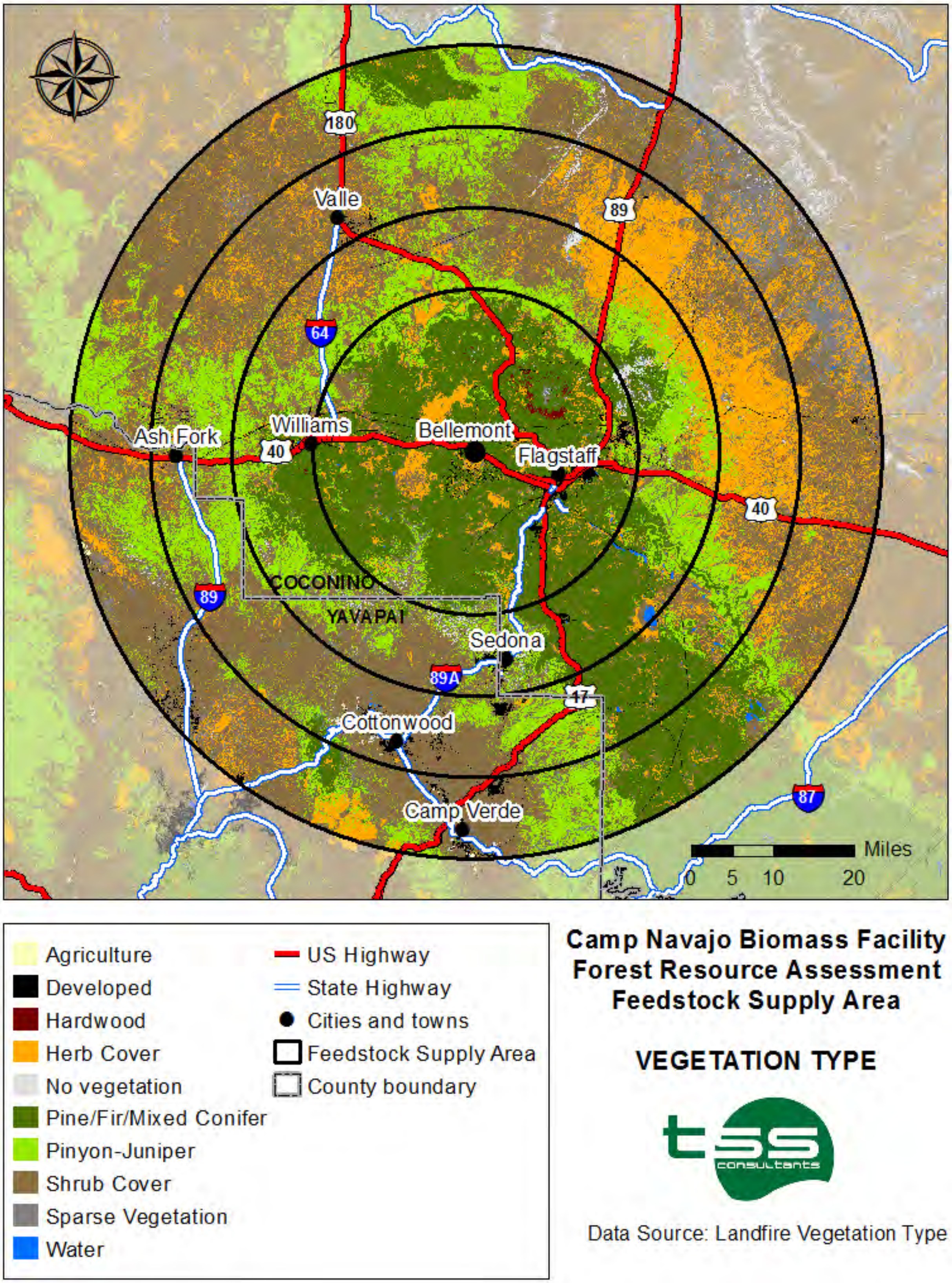
- Juniper removal as a byproduct of Pinyon-Juniper grassland restoration activities.

Vegetation Cover

Woody biomass availability for any given region is heavily dependent on vegetation cover, topography, land management objectives and ownership. Figure 13 highlights the vegetation cover types spatially distributed across the Camp Navajo FSA. TSS utilized US Department of Agriculture and Department of Interior LANDFIRE[41] data to assess vegetation cover types. The vegetation cover types are categorized to account for spatial distribution of dominant vegetation (e.g., pine/fir/mixed conifer, shrub, herb, pinyon-juniper).

[41] LANDFIRE is a shared program between the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior's wildland fire management bureaus under the direction of the Wildland Fire Leadership Council (WFLC). Landfire produces a comprehensive, consistent, scientifically based suite of spatial layers and databases for the entire United States and territories.

Figure 13. Vegetation Cover Type Distribution Within the Camp Navajo FSA



Vegetation cover types influence woody biomass availability. Depending on management objectives, certain cover types could generate significant volumes of woody biomass material for use as feedstocks for value-added utilization (including bioenergy production). Table 1 summarizes vegetation cover by type within the FSA.

Table 1. Vegetation Cover Acreage by Radius Within the Camp Navajo FSA

VEGETATION COVER	20 MILE	30 MILE	40 MILE	50 MILE
Agriculture	1	8	210	1,365
Developed	32,354	46,815	69,912	92,381
Hardwood	5,233	5,486	5,557	5,584
Herb Cover	71,748	182,526	463,959	668,937
No Vegetation	3,730	17,842	23,766	30,502
Pine/Fir/Mixed Conifer	517,755	708,437	799,709	968,203
Pinyon-Juniper	69,839	366,918	639,069	917,886
Shrub Cover	93,249	447,321	1,150,243	2,129,849
Sparse Vegetation	9,576	30,507	58,755	203,577
Water	763	3,700	5,818	8,258
TOTAL ACRES	**804,248**	**1,809,560**	**3,216,998**	**5,026,544**

The vegetative cover that will generate biomass material for use as fuel are the pine/fir/mixed conifer (968,203 acres) and pinyon-juniper (917,886 acres) cover types. Together these cover types represent approximately 37% of the total acreage within the 50-mile FSA. Figure 14 provides a graphic depiction of vegetation cover type distribution across the 50-mile FSA.

Figure 14. Vegetation Type Distribution Chart 50-Mile FSA

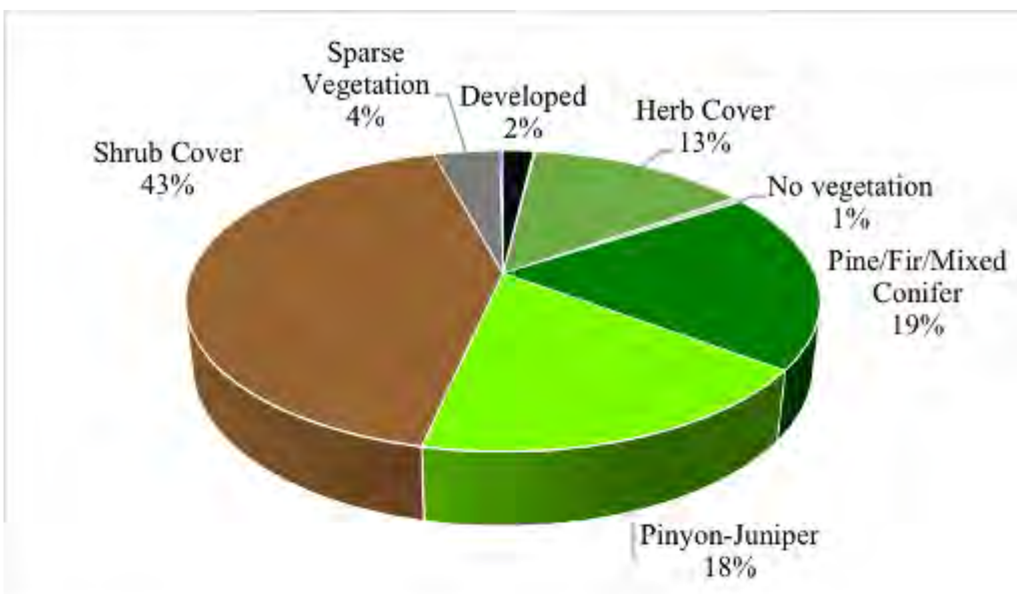
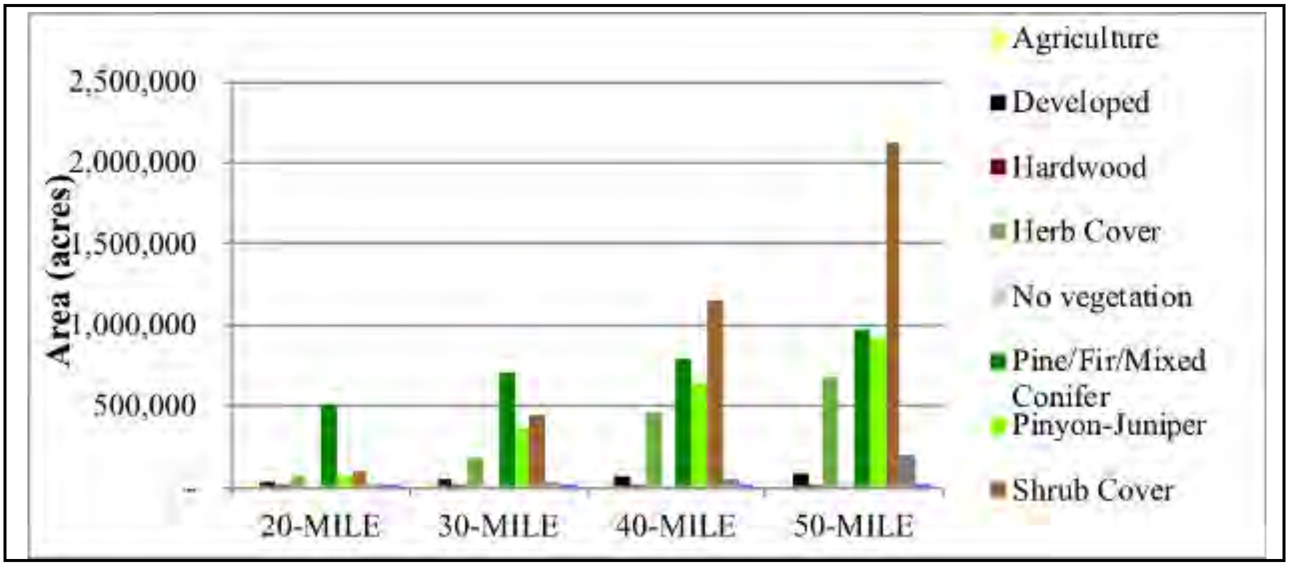


Figure 15 provides a bar graph depiction of vegetation types across the various radii that make up the FSA.

Figure 15. Vegetation Cover Type Distribution Graph Across the Camp Navajo FSA



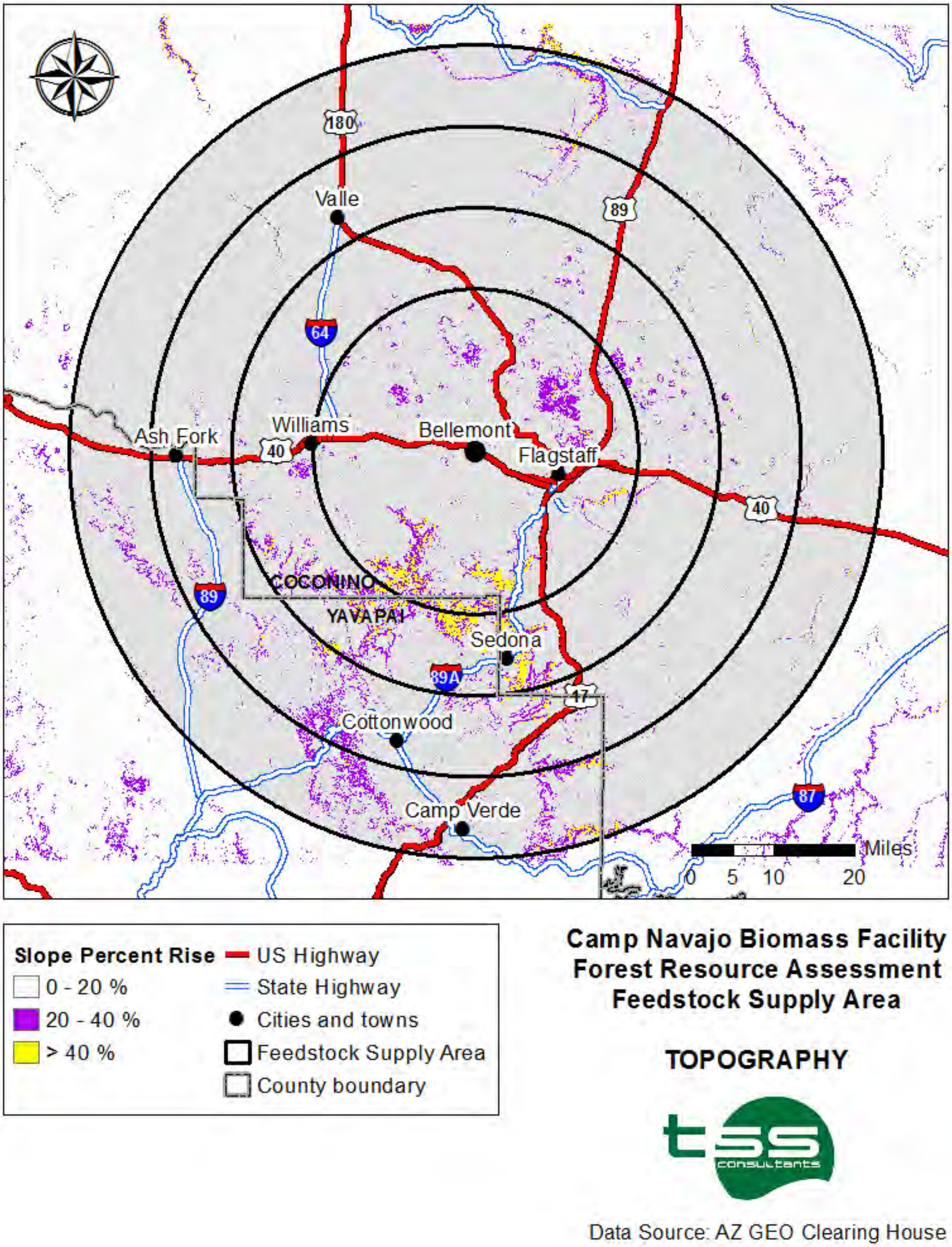
Terrain

Forest and pinyon-juniper grassland (PJ) biomass collection activities are restricted to topography that will allow ready access for equipment and crew. Steep topography over 40% slope gradient is considered to be the break off point for ground-based logging and/or biomass recovery equipment on federally managed lands (US Forest Service and Bureau of Land Management) and on Camp Navajo.[42] Private land managers typically utilize ground-based equipment on slopes up to 50%, but the cost of operating on sustained slopes above 40% are typically quite high and are considered prohibitive. Areas with 40% slope or higher are highlighted in Figure 16. TSS utilized AZ GEO Clearinghouse[43] data to assess slope gradient across the FSA.

[42] The Flagstaff Watershed Protection Program does allow biomass removal on steeper slopes (to facilitate fuels reduction in a sensitive domestic watershed).

[43] The AZ GEO Clearinghouse is an initiative of the Arizona Geographic Information Council. AZ GEO is designed to provide GIS users with links to Internet map services, FGDC compliant metadata, and geospatial data downloads. AZ GEO is maintained and hosted by the Arizona State Land Department.

Figure 16. Steep Terrain Within the Camp Navajo FSA



Note that most of the landscape with 40% plus slope gradient is concentrated in riparian areas near Sedona that are typically considered critical habitat (for wildlife) and are not usually targeted for traditional fuels treatment or grassland restoration activities. Table 2 summarizes the results of the slope gradient analysis across the FSA. Less than 1% of the total FSA has steep terrain with slope gradient exceeding 40%.

Table 2. Slope Gradient Within the Camp Navajo FSA

SLOPE GRADIENT	ACRES	% OF TOTAL
<10 %	4,347,584	86.49%
10 - 20 %	476,767	9%
20 - 30 %	152,280	3%
30 - 40 %	41,738	1%
>40 %	8,193	0.16%
TOTAL SURFACE (ACRES)	**5,026,561**	**100%**

Land Ownership

Within the forest and PJ vegetation type acreage, land ownership drives vegetation management objectives and activities. Figure 17 highlights the location of various ownerships and jurisdictions. TSS utilized AZ GEO Clearinghouse[44] data to assess land ownership across the FSA. Tables 3 through 6 summarize land ownership and vegetation type within each of the radii making up the FSA.

[44] Ibid.

Figure 17. Land Ownership Within the Camp Navajo FSA

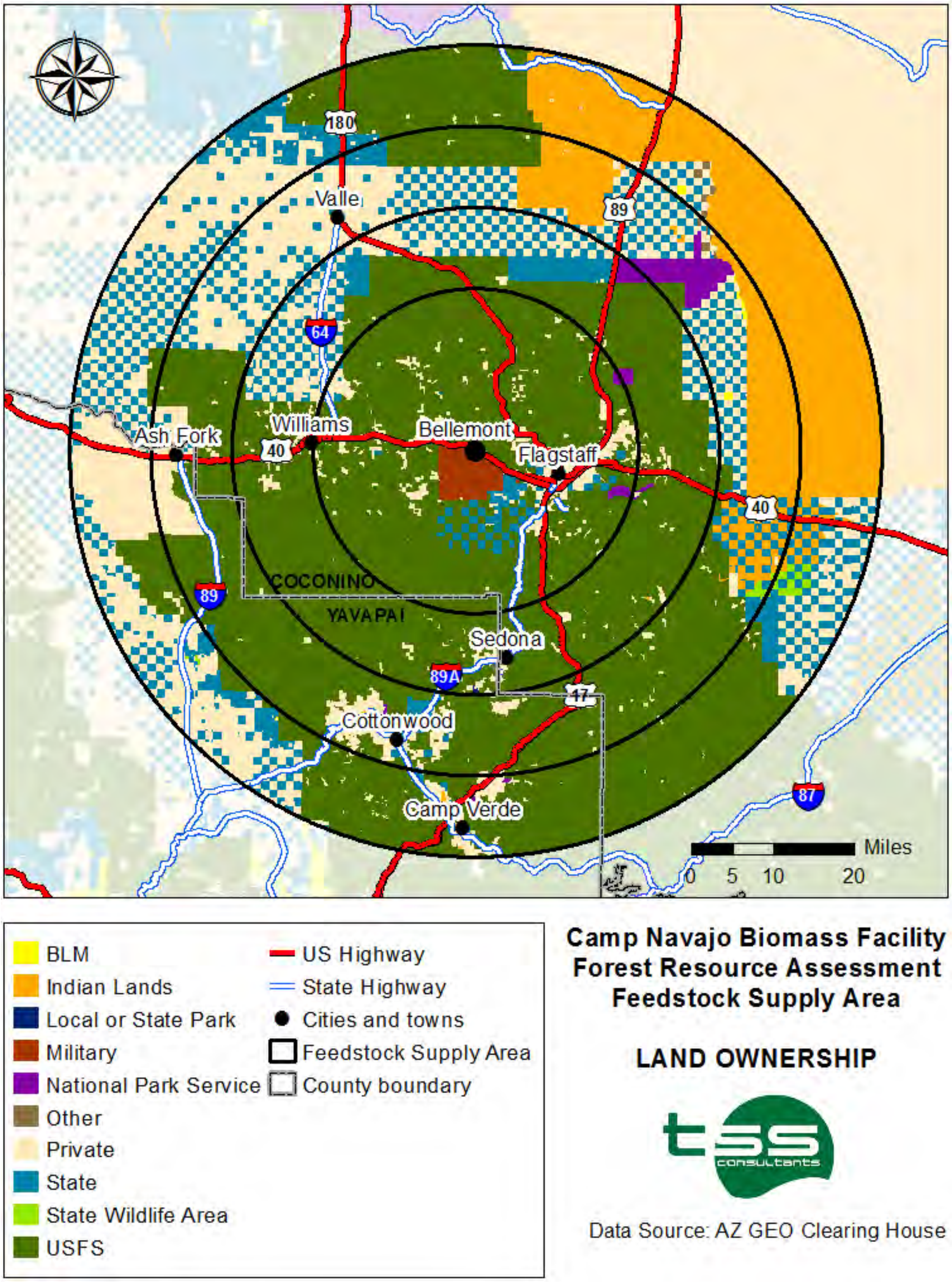


Table 3. Land Ownership by Vegetation Type Within 50-Mile FSA

(Key vegetation types highlighted in yellow)

VEG TYPE	BLM	TRIBAL	LOCAL OR STATE PARK	MILITARY	NAT'L PARK SERVICE	OTHER	PRIVATE	STATE	STATE WILD-LIFE AREA	US FOREST SERVICE	TOTAL ACRES
Agriculture	-	8	0	-	0	-	1,267	72	1	18	1,365
Developed	1	3,135	132	2,655	514	113	58,301	3,400	106	24,025	92,381
Hardwood	-	-	-	14	-	-	178	5	-	5,388	5,584
Herb Cover	527	169,876	11	3,533	22,643	921	168,955	132,644	2,596	167,233	668,937
No vegetation	58	7,037	-	24	1,899	6	4,048	1,604	-	15,826	30,502
Pine/Fir/ Mixed Conifer	**-**	**51**	**-**	**18,717**	**2,410**	**-**	**29,672**	**24,336**	**70**	**892,947**	**968,203**
Pinyon-Juniper	**71**	**14,617**	**95**	**182**	**960**	**52**	**122,010**	**77,237**	**1,531**	**701,132**	**917,886**
Shrub Cover	1,706	308,290	1,057	4,240	11,472	2,022	647,619	365,350	5,703	782,390	2,129,849
Sparse Vegetation	181	117,917	30	275	1,867	1,165	27,922	13,639	24	40,556	203,577
Water	1	974	31	17	6	26	998	33	5	6,167	8,258
TOTALS	**2,545**	**621,905**	**1,356**	**29,657**	**41,772**	**4,304**	**1,060,969**	**618,318**	**10,036**	**2,635,681**	**5,026,544**

Table 4. Land Ownership by Vegetation Type Within 40-Mile FSA

(Key vegetation types highlighted in yellow)

VEG TYPE	BLM	TRIBAL	LOCAL OR STATE PARK	MILITARY	NAT'L PARK SERVICE	OTHER	PRIVATE	STATE	STATE WILD-LIFE AREA	US FOREST SERVICE	TOTAL ACRES
Agriculture	-	1	0.1	-	0.1	-	194	0.4	0.1	14	210
Developed	-	455	121	2,584	514	108	43,672	2,181	97	20,180	69,912
Hardwood	-	-	-	14	-	-	178	5	-	5,361	5,557
Herb Cover	459	89,227	11	3,518	22,643	449	117,103	96,629	620	133,301	463,959
No vegetation	57	2,454	-	24	1,899	1	3,201	1,409	-	14,721	23,766
Pine/Fir/ Mixed Conifer	-	50	-	18,717	2,410	-	28,587	24,130	70	725,744	799,709
Pinyon-Juniper	61	4,706	93	182	960	52	67,776	44,102	1,172	519,966	639,069
Shrub Cover	1,012	79,986	1,019	3,366	11,472	1,042	305,114	173,827	862	572,544	1,150,243
Sparse Vegetation	136	9,852	30	258	1,867	115	8,913	6,142	4	31,438	58,755
Water	1	133	31	17	6	2	756	22	1	4,850	5,818
TOTALS	**1,725**	**186,863**	**1,305**	**28,680**	**41,772**	**1,768**	**575,494**	**348,447**	**2,826**	**2,028,120**	**3,216,998**

Table 5. Land Ownership by Vegetation Type Within 30-Mile FSA

(Key vegetation types highlighted in yellow)

VEG TYPE	BLM	TRIBAL	LOCAL OR STATE PARK	MILITARY	NAT'L PARK SERVICE	OTHER	PRIVATE	STATE	STATE WILD-LIFE AREA	US FOREST SERVICE	TOTAL ACRES
Agriculture	-	-	-	-	-	-	3	-	-	5	8
Developed	-	-	17	2,584	259	106	27,821	1,169	55	14,805	46,815
Hardwood	-	-	-	14	-	-	176	5	-	5,292	5,486
Herb Cover	-	66	8	3,518	5,816	0	35,593	31,225	-	106,301	182,526
No vegetation	-	-	-	24	1,767	-	1,536	999	-	13,516	17,842
Pine/Fir/ Mixed Conifer	-	-	-	18,717	2,410	-	27,705	23,876	2	635,727	708,437
Pinyon-Juniper	-	-	84	182	940	52	36,106	24,465	0	305,090	366,918
Shrub Cover	-	33	229	3,366	675	76	93,888	75,847	3	273,204	447,321
Sparse Vegetation	-	-	0	258	539	1	3,148	2,893	0	23,668	30,507
Water	-	0	-	17	1	-	344	13	-	3,326	3,700
TOTALS	**-**	**99**	**338**	**28,680**	**12,407**	**235**	**226,318**	**160,491**	**60**	**1,380,934**	**1,809,560**

Table 6. Land Ownership by Vegetation Type Within 20-Mile FSA

(Key vegetation types highlighted in yellow)

VEG TYPE	BLM	TRIBAL	LOCAL OR STATE PARK	MILITARY	NAT'L PARK SERVICE	OTHER	PRIVATE	STATE	STATE WILD-LIFE AREA	US FOREST SERVICE	TOTAL ACRES
Agriculture	-	-	-	-	-	-	1	-	-	0.2	1
Developed	-	-	5	2,584	37	-	19,848	553	55	9,272	32,354
Hardwood	-	-	-	14	-	-	162	5	-	5,052	5,233
Herb Cover	-	-	-	3,518	8	-	12,284	3,232	-	52,706	71,748
No vegetation	-	-	-	24	687	-	271	4	-	2,744	3,730
Pine/Fir/ Mixed Conifer	-	-	-	18,717	1,641	-	24,286	23,464	2	449,645	517,755
Pinyon-Juniper	-	-	-	182	326	-	3,920	1,360	0.1	64,051	69,839
Shrub Cover	-	-	-	3,366	172	-	16,059	5,056	3	68,594	93,249
Sparse Vegetation	-	-	-	258	172	-	744	91	0.2	8,310	9,576
Water	-	-	-	17	1	-	191	6	-	549	763
TOTALS	**-**	**-**	**5**	**28,680**	**3,044**	**-**	**77,766**	**33,770**	**60**	**660,923**	**804,248**

Key land ownerships that manage significant acreages of forest and PJ grasslands include US Forest Service, State lands, private lands and military (primarily Camp Navajo). These are summarized in Table 7 and Table 8.

Table 7. Key Land Ownerships Within PJ Grassland Vegetation Type

OWNERSHIP	20 MILE		30 MILE		40 MILE		50 MILE	
	PJ ACRES	% OF TOTAL	PJ ACRES	% OF TOTAL	PJ ACRES	% OF TOTAL	PJ ACRES	% OF TOTAL
US Forest Service	64,051	92%	305,090	83%	519,966	81%	701,132	76%
Private/Tribal	3,920	6%	36,106	10%	67,776	11%	122,010	13%
State Lands	1,360	2%	24,465	7%	44,102	7%	77,237	8%
Other*	326	0%	1,076	0%	7,043	1%	17,326	2%
Military	182	0%	182	0%	182	0%	182	0%
TOTALS	**69,839**	**100**	**366,918**	**100**	**639,069**	**100**	**917,886**	**100**

**Primarily local, state and federal parks.*

Table 8. Key Land Ownerships Within Forest Vegetation Type

OWNERSHIP	20 MILE		30 MILE		40 MILE		50 MILE	
	FOREST ACRES	% OF TOTAL	FOREST ACRES	% OF TOTAL	FOREST ACRES	% OF TOTAL	FOREST ACRES	% OF TOTAL
US Forest Service	449,645	87%	635,727	90%	725,744	91%	892,947	92%
Private/Tribal	24,286	5%	27,705	4%	28,587	4%	29,672	3%
State Lands	23,464	5%	23,876	3%	24,130	3%	24,336	3%
Military	18,717	4%	18,717	3%	18,717	2%	18,717	2%
Other*	1,643	0%	2,412	0%	2,530	0%	2,531	0%
TOTALS	**517,755**	**100**	**708,437**	**100**	**799,709**	**100**	**968,203**	**100**

**Primarily local, state and federal parks.*

Key observations regarding the outcome of the land ownership analysis include the following.

- US Forest Service, State lands and private lands are the key ownership categories managing almost 100% of the PJ dominated acreage and 98% of the forest dominated acreage.

- US Forest Service manages most of the forest (92%) and PJ (76%) acreage across all four of the radii making up the FSA.

- Private lands represent the number two ranked ownership category with 13% of forest and 13% of PJ acreage across all four radii making up the FSA.

- State lands represent the number three ranked ownership category with 2% of forest and 8% of PJ acreage across all four radii making up the FSA.

Forest Feedstock

A total of 968,203 acres of conifer forest dominated landscape are located within the Camp Navajo FSA. This represents the single most significant vegetation cover type and is likely to produce the highest volume of biomass material of the various cover types found within the FSA.

Forest operations can provide significant volumes of woody biomass material. Typically available as limbs, tops, and sub-merchantable logs, these residuals are byproducts of commercial timber harvesting, fuels reduction and timber stand improvement operations. In northern Arizona, fuels reduction and timber stand improvement activities are integrated with commercial timber harvest operations and generate significant volumes of harvest residuals. These residuals currently have little to no merchantable value[45] but can be a relatively economic source of biomass feedstock for use as fuel in a bioenergy facility located within economic haul distance. Once collected and processed using portable chippers or grinders, this material is an excellent fuel source due to the relatively high heat value (8,000 to 8,800 Btu/dry pound) and relatively low ash content (typically less than 4% by dry weight).[46]

Small, sub-merchantable[47] logs that do not meet sawlog or firewood specifications could also be recovered from forest treatment operations. In some cases, the larger logs (e.g., six-inch and larger diameter measured small end inside bark) command a higher value, which could leave the smaller logs available (e.g., under six-inch diameter) for value-added utilization. These smaller logs can be diverted to value-added uses such as posts or poles, firewood, or as raw material feedstock for animal bedding, compost, landscape cover, or fuel for biomass power generation.

Forest feedstock availability is very dependent upon forest ownership land management objectives and a ready market for sawlogs. As noted in Table 8, essentially all of the forestland is managed by four distinct ownerships: US Forest Service, State lands, private lands and Camp Navajo.

US Forest Service

The US Forest Service (USFS) manages about 892,947 acres of forest land within the FSA. As noted earlier, this is the single largest forest ownership within the FSA at 92% of total conifer forest cover type. Interviews with USFS staff[48] confirmed that most of the timber harvest and restoration activities within the Camp Navajo FSA are integrated into the Four Forest Restoration Initiative (4FRI) that includes multiple contract types and stewardship agreements.

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[45] Per discussions with local timber harvest contractors.
[46] Data presented is from ponderosa pine feedstock sample testing conducted by TSS in Oregon and California.
[47] Sub-merchantable material = small stems, typically under 6” diameter at breast height, that are too small to be manufactured into merchantable forest products (e.g., lumber).
[48] Dick Fleishman, Operations Coordinator, Four Forests Restoration Initiative.

The largest current contract holder is Good Earth Power (holds the 4FRI Phase I stewardship contract).

The primary goal of the 4FRI effort is to treat targeted landscapes to restore the structure, pattern and composition of ponderosa pine forests that will provide the added benefits of fuels reduction, forest health, and wildlife/plant diversity. The goal is to treat 50,000 acres per year with mechanical harvest.[49] A key objective is to maintain and enhance sustainable ecosystems in the long term. A total of 300,000 acres of forest landscapes (primarily ponderosa pine cover type) are targeted for treatment in Phase I of 4FRI.

Phase I of 4FRI was initially awarded to Pioneer Forest Products, but Pioneer was not able to secure capital financing for a planned forest products manufacturing facility at Winslow, Arizona. Pioneer transferred the 4FRI contract to Good Earth Power (GEP) in September 2013 (with USFS concurrence). After three years of implementation (with mixed results), GEP teamed with an investment group to form NewLife Forest Products. NewLife is currently focused on building, owning and operating sawmills that would receive sawlogs from 4FRI (and other forest ownerships). NewLife is currently operating a sawmill at Heber, Arizona (formerly known as Lumberjack Timber, LLC) and is in the process of developing a sawmill at Williams.[50] For additional information regarding NewLife Forest Products, see Forest Products Manufacturing section.

Due to a very limited market for sawlogs and forest operations residuals (biomass), GEP and other contractors have struggled keeping pace with task orders issued and timber sales awarded by the USFS. Only 10,636 acres have been treated so far within 4FRI Phase I contract; 2,554 of those acres have been harvested within the FSA. Other contractors have harvested 17,200 acres since 2010 within the FSA. The limited acres treated within the project area are primarily due to the requirement to remove biomass within the 4FRI Phase I contract and a lack of sawlog and forest biomass markets within economic haul distance. The termination date for the 4FRI Phase I stewardship contract is May 2022.

Figure 18 is a map showing the location of both the first Environmental Impact Statement (EIS) Project Area (4FRI Phase I) and the Rim Country EIS Project Area (4FRI Phase II). The 4FRI landscape is unique in that it has significant portions of the target treatment area covered with completed National Environmental Policy Act (NEPA) analysis that is usually a hindrance to working on USFS managed land (as shown in Figure 18). These large-scale NEPA projects, as well as other smaller scale NEPA projects, are the groundwork for the 4FRI Phase I contract, other sales and Stewardship Agreements that are making wood fiber available to markets, and will also be the cornerstone for a new solicitation for a long-term contract, 4FRI Phase II. The USFS is scheduled to issue a request for proposals regarding 4FRI Phase II in early 2019.

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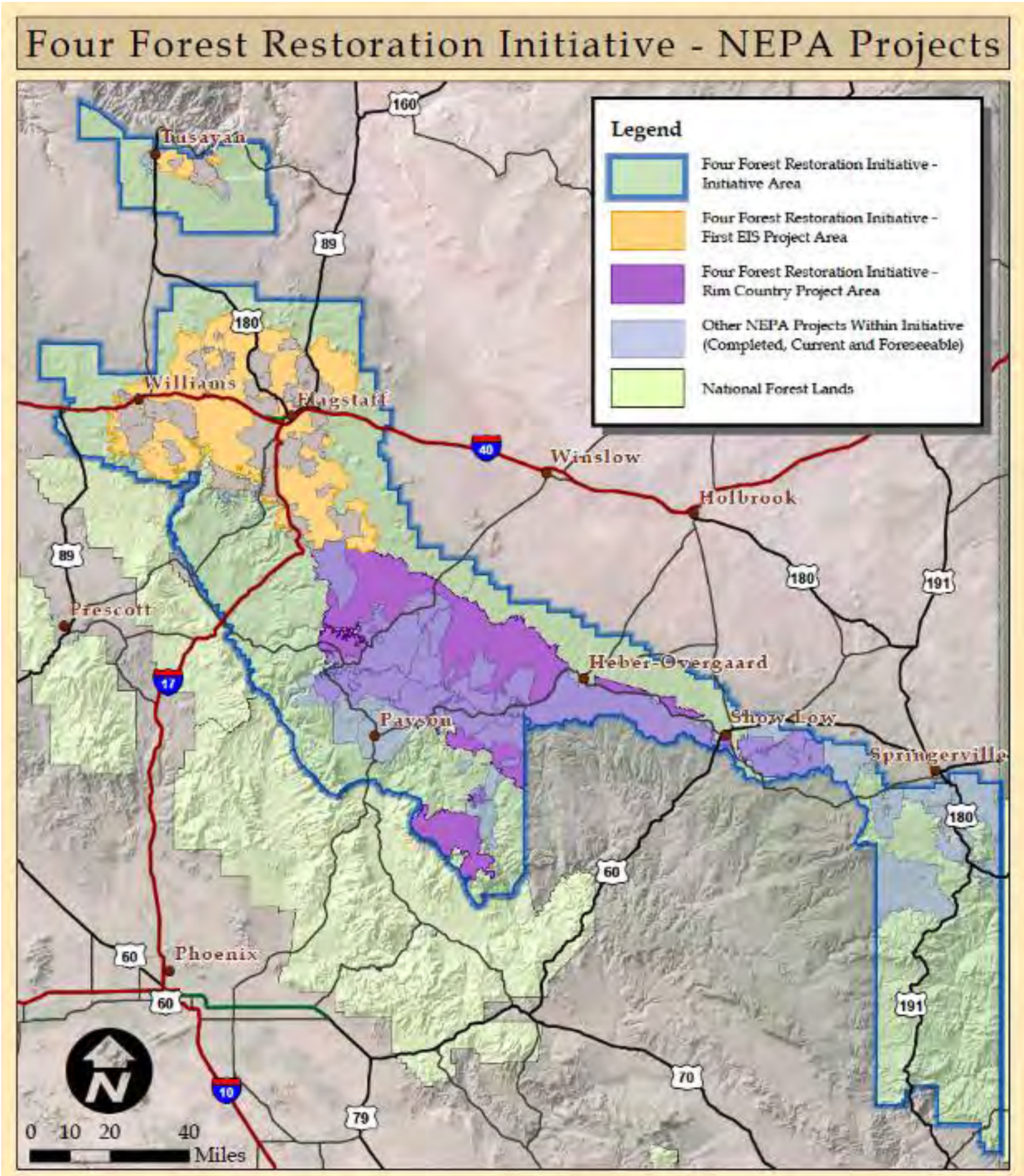
[49] Strategic Plan available online here: 4FRI Strategic Plan.
[50] Per discussions with Adam Cooley, Director, Sales and Manufacturing, NewLife Forest Products.

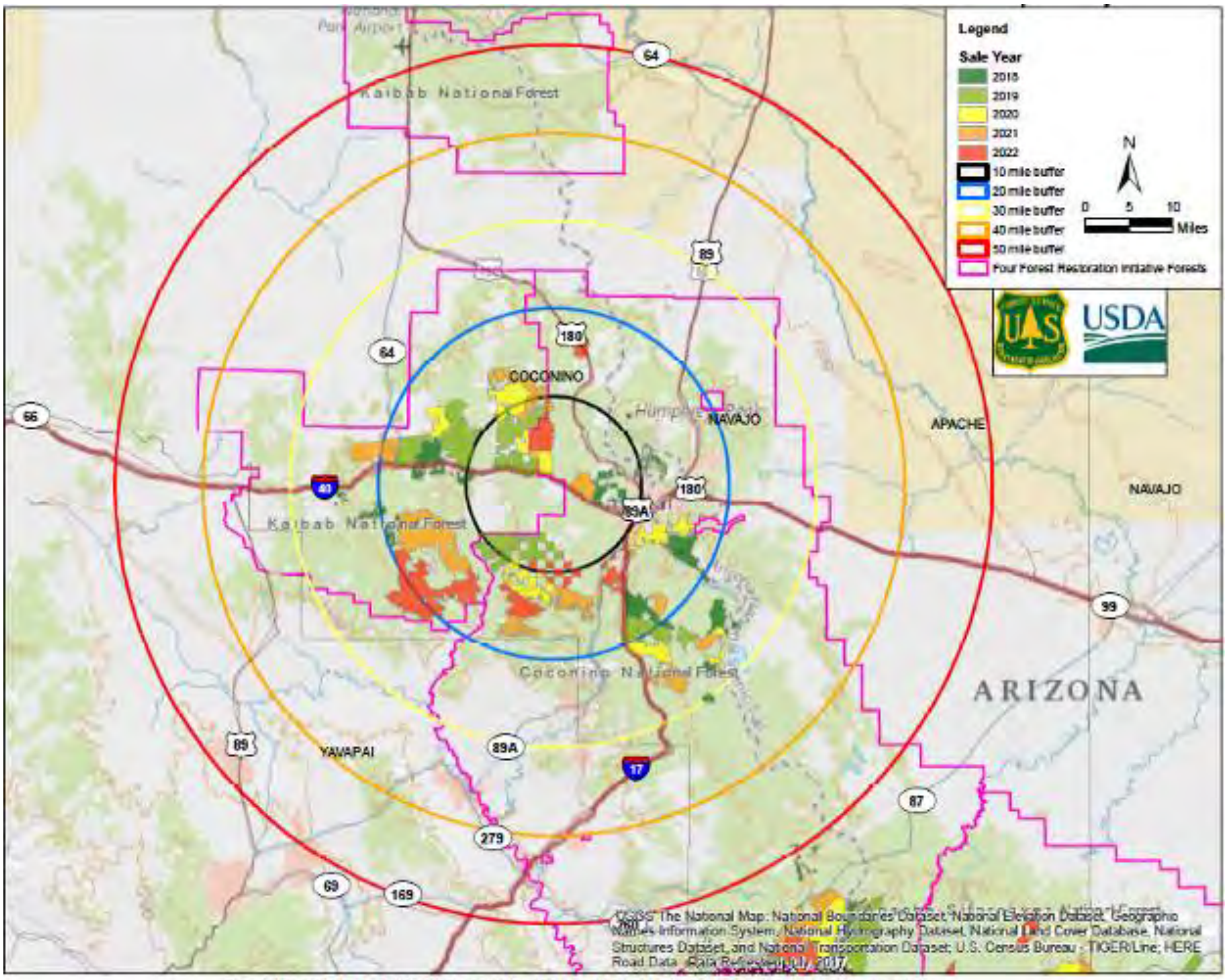
Figure 18. Four Forest Restoration Initiative Completed NEPA



Source: US Forest Service

A map highlighting targeted projects planned for implementation over a five-year period (2018 through 2022) was provided by USFS staff.[51] Figure 19 highlights the location of these projects.

Figure 19. Four Forest Restoration Initiative 2018 Through 2022 Planned Projects



USFS staff provided a 2018 through 2022 project level treatment forecast to accompany the treatment area map presented above. Over these five years, the agency hopes to treat approximately 22,000 acres per year[52] within the Camp Navajo FSA. Historically, the USFS has treated about 2,800 acres per year.[53]

Recently, the USFS has offered 11 timber removal contracts[54] totaling 13,794 acres of treatment and received no bids.[55] This is indicative of a region with very limited markets for sawlogs and forest biomass. It is critical that a ready market for sawlogs be developed if the pace and scale of

[51] Dick Fleishman, Operations Coordinator, Four Forests Restoration Initiative.
[52] This includes all projects on USFS managed lands within the Camp Navajo FSA.
[53] 2010 through 2017 accomplishments within the Camp Navajo FSA, provided by Dick Fleishman.
[54] 7,628 acres and four projects were timber sales, 6,166 acres and seven projects were Integrated Resource Service Contracts.
[55] Data provided by Dick Fleishman, 4FRI Operations Coordinator.

forest treatments are to increase over time to meet USFS objectives. NewLife Forest Products and Perkins Forest Products are currently developing sawmills near Williams (see Forest Products Manufacturing section). TSS assumes that by 2020, a sawlog market will be active as these sawmills are developed and operate at commercial-scale. Coupled with a bioenergy facility at Camp Navajo (or Bellemont) that offers a ready market for forest-sourced biomass; TSS forecasts that USFS will be able to increase forest treatments to 7,500 acres per year commencing in 2020.

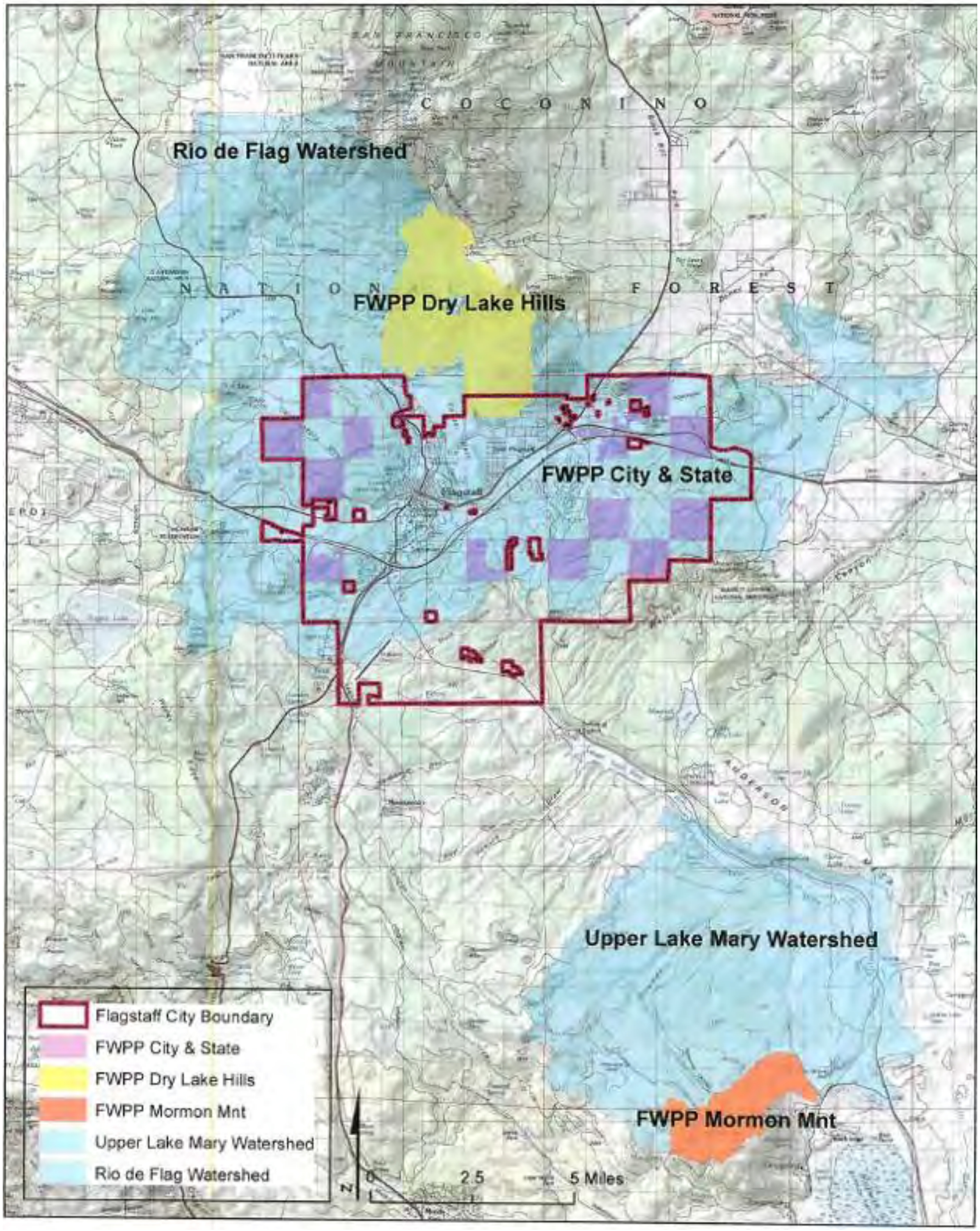
Flagstaff Watershed Protection Plan

In addition to activities associated with 4FRI, the USFS is also working in partnership with the City of Flagstaff, Coconino County, and Arizona Department of Forestry and Fire Management in support of the Flagstaff Watershed Protection Project (FWPP). In November 2012, the residents of Flagstaff voted in favor of a $10 million bond to support forest restoration efforts within strategic watersheds located on the Coconino NF and on State lands. The FWPP is one of several examples in the U.S. where municipalities are investing in targeted watersheds managed by public agencies. A primary concern is the impact of catastrophic wildfire on domestic watersheds that serve municipalities (like Flagstaff).

Current plans target fuels treatment and forest restoration work on 11,600 acres in the Rio de Flag and Upper Lake Mary watersheds by 2022. Approximately 4,000 acres of treatment have been accomplished so far.[56] Figure 20 provides the location of these watersheds and FWPP project locations.

[56] Paul Summerfelt presentation on June 4, 2018 to joint session of the Flagstaff City Council and Coconino County Board of Supervisors.

Figure 20. Flagstaff Watershed Protection Project Treatment Areas



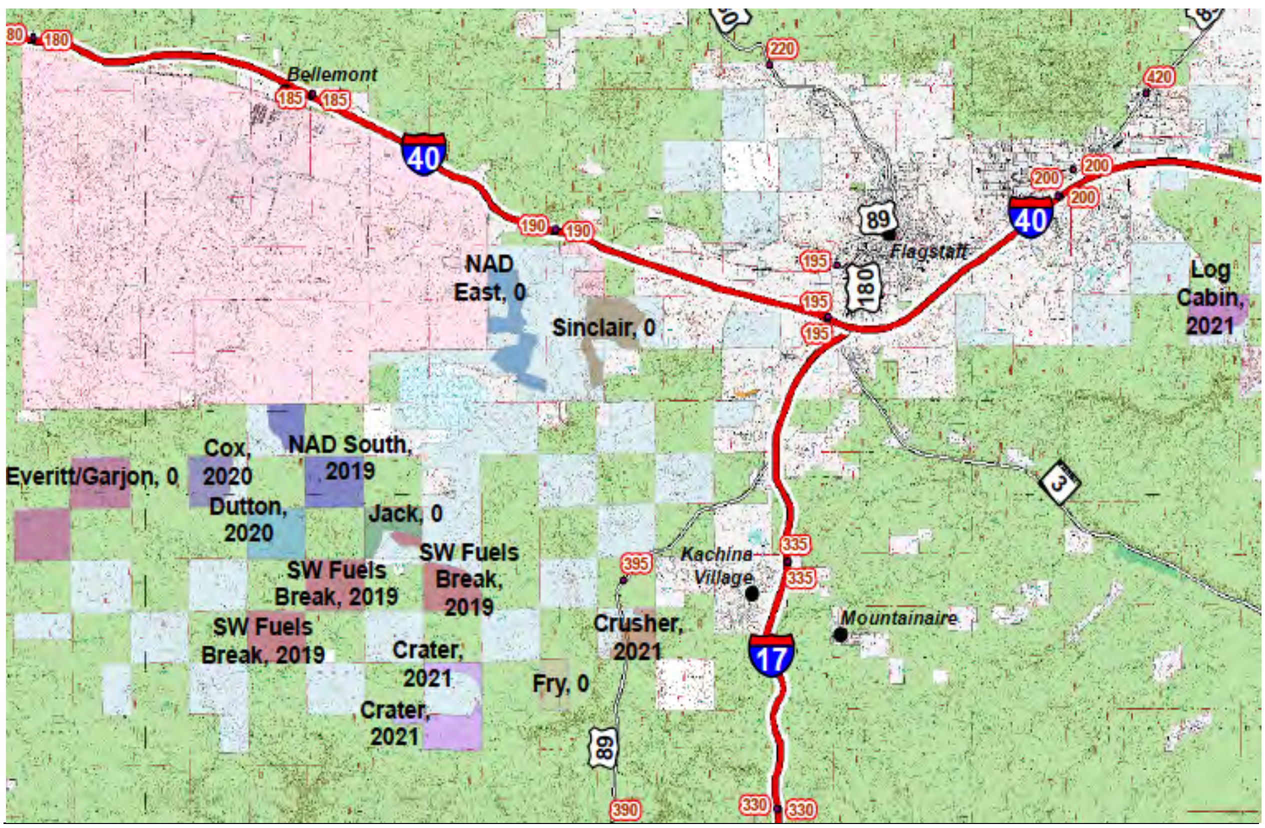
Source: Coconino County

Projects scheduled for 2019 through 2021 implementation are focused on steep terrain in the Dry Lake Hills area and will require cable logging equipment and/or helicopter logging.[57] This terrain will limit forest biomass recovery due to challenging slopes and limited road access. However, the material that is removed will be decked and sold (potentially available for processing into biomass fuel). A recent Integrated Resource Service Contract request for proposals associated with the FWPP in 2018 received no bidders.

State Lands

Arizona State Trust lands include 24,336 acres of forest landscape within the FSA, which makes up about 3% of total forest acreage. Discussions with Arizona State Division of Forestry and Fire Management (ADFFM) staff[58] confirmed that forest management activities on State lands are very dependent upon grant funding (primarily federal funds) and ready markets for sawlogs and forest biomass. ADFFM staff forecasts that approximately 1,800 to 2,000 acres per year of forest are targeted for treatment within the FSA in the coming years. Figure 21 highlights the locations of forest projects planned on State Trust lands through 2021.

Figure 21. State Trust Land Forest Management Projects Planned Through 2021



Source: AZ Division of Forestry and Fire Management

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[57] Two contracts were awarded in mid-October 2018 to firms that will conduct helicopter removal and likely a skyline logging system removal on about 900 acres of steep terrain.
[58] Aaron Green, District Manager and Keith Pajkos, Forester, Arizona Division of Forestry and Fire Management.

Camp Navajo

The AZARNG manages Camp Navajo, a heavily forested 28,500-acre property located due west of Flagstaff near Bellemont, Arizona. Approximately 18,700 acres of the Camp are forested, making up 2% of total forest area within the FSA.

The AZARNG natural resources staff updated the Camp Navajo Integrated Natural Resources Management Plan in December 2017. The plan is focused on forest treatment activities that will reduce the incidence of large catastrophic wildfires and restore forest resiliency and function consistent with the installation's military mission. The Camp Navajo forester[59] confirmed plans to treat about 13,554 acres and provided a 10-year forecast of forest treatment plans (2020 through 2029). An average of 1,355 acres per year are planned for treatment using a variety of prescriptions including group selection, evidence based restoration, and intermediate thinning.

Interviews with local logging contractors[60] that have conducted operations on Camp Navajo confirmed a biomass removal rate of approximately one truckload per acre. This removal rate assumes sawlog removals at approximately 24 green tons per acre, with timber harvest residuals (limbs, tops) and small stems (sub-merchantable trees 3" to 9" diameter at breast height) making up the biomass material removed. At 16 bone dry tons (BDT)[61] per truckload, over 21,680 BDT per year of forest biomass could be available commencing in 2020. The Camp Navajo forester confirmed that while all forest operations residuals generated as a result of timber harvest, fuels treatment, and forest restoration activities are currently piled and burned, there is a strong preference for collection, processing, and removal of this material.

Flagstaff Fire Department

The Flagstaff Fire Department is currently managing fuels treatment projects within the community of Flagstaff. Discussions with Flagstaff Fire Department staff[62] confirmed that the department is continuing to sponsor fuels treatment projects strategically located within the wildland urban interface. Most of the material that is thinned is processed into personal use firewood, and the residuals (limbs and tops) are piled and burned onsite. Some of this residual material could be collected and processed for use as feedstock. Between 100 and 150 acres are treated annually.

Private

Private forest lands within the FSA total about 29,672 acres, making up approximately 3% of conifer forest cover type in the FSA. There are no records available regarding historic pace and scale of forest management activities on private lands. Interviews with local logging contractors confirm relatively little forest management activity on private lands due to the poor market for sawlogs. Discussions with ADFFM staff[63] confirmed that most of the private forest land is made up of small ownerships (10 to 20 acres) that are not managed for commercial timber production.

[59] Nick Kainrath, Forester, Arizona Army National Guard.
[60] High Desert Investments, Perkins Timber Harvesting.
[61] One bone dry ton is equal to 2,000 pounds of wood fiber at 0% moisture content. BDT is the industry standard unit of measure for feedstock volume.
[62] Paul Summerfelt and Matt Millar, Flagstaff Fire Department.
[63] Aaron Green, District Manager, Arizona Department of Forestry and Fire Management.

Private forest landowners are very focused on projects that minimize cost per acre or generate net revenue. There is some funding administered by the ADFFM that matches private investment in fuels reduction and forest health ranging from 50/50 to 90/10 cost share.[64] For the purposes of this analysis, TSS estimates 500 acres per year of forest treatment on private land if a ready market existed for sawlogs and forest biomass.

Forest Products Manufacturing

A primary market driver influencing active timber management for any given region is demand for sawlogs. This is especially the case for northern Arizona. Interviews with timber sale purchasers[65] active in the region (primarily on the Coconino NF and Kaibab NF) confirmed that sawlog markets are not well developed. However, there appears to be strong interest for new investment in expansion and upgrading of existing sawmills in the region.[66] The primary reason for additional investment in sawmill infrastructure is the current lack of existing sawlog markets and the expected continued interest by the USFS in the implementation of Phase I and Phase II of the 4FRI stewardship contract.

Currently there are five commercial sawmills within or tributary to the FSA, along with two firewood operations (purchasing firewood logs). All seven operations procure roundwood (sawlogs and firewood logs) harvested within the FSA and are summarized below:

- Perkins Forest Products sawmill at Williams
- NewLife Forest Products, LLC sawmill at Heber
- White Mountain Apache Timber Company sawmill at White River
- Southwest Forest Products sawmill at Phoenix
- Pallet and Lumber Supply sawmill at Phoenix
- Canyon Wood firewood operation at Camp Verde
- High Desert Firewood operation at Winslow

As noted earlier, a robust forest products manufacturing sector is key to active forest management within a given region. In addition, forest products manufacturing facilities generate residuals in the form of sawdust, bark, chips and planer shavings. These residuals are an excellent biomass feedstock.

The Perkins Forest Products sawmill at Williams is located closest to Camp Navajo (20-mile one-way distance) and is currently being upgraded to produce about 50,000 board foot per day by spring 2019.[67] At full production, this mill is forecast to generate about 17,500 BDT per year of residuals potentially available as biomass fuel.

Discussions with NewLife Forest Products, LLC staff[68] confirmed plans to develop a commercial-scale sawmill just east of Williams along Garland Prairie Road (not far from Perkins Forest Products operation). NewLife plans to have full-scale commercial operations underway

[64] State Fire Assistance grants (50/50 cost share) and Wildland Fire Hazardous Fuels grants (90/10 cost share).
[65] High Desert Investments, Perkins Timber Harvesting, and Northern Arizona Procurement Company.
[66] Discussions with Perkins Timber Harvesting, NewLife Forest Products.
[67] Per discussions with James Perkins, Perkins Forest Products.
[68] Adam Cooley, Director, Sales and Manufacturing, NewLife Forest Products.

by fall of 2020. First phase is a chip and saw mill, followed soon thereafter with a conventional sawmill operation including lumber drying capacity (biomass fired kilns). Operating on a two-shift basis, NewLife staff estimate that approximately 59,500 BDT per year of sawdust could be available as biomass fuel. NewLife feels that markets for bark (landscape cover), chips (pulp and paper or composite panels), and planer shavings (animal bedding and fuel for lumber kilns) will offer better market prices than biomass fuel feedstock.

Findings

Summarized below in Table 9 are TSS findings regarding residuals potentially available from forest operations, fuels reduction activities, and forest products manufacturing. A recovery factor of 16 BDT per acre[69] was utilized to calculate forest residual volume produced annually.

Table 9. Potentially Available Forest Operations and Forest Products Residuals Supply

FEEDSTOCK	ACRES TREATED/ YEAR	POTENTIAL VOLUME AVAILABLE (BDT)
Forest Operations – Federal	7,500	120,000
Forest Operations – State	1,800	28,800
Forest Operations – Camp Navajo	1,355	21,680
Forest Operations – Private	500	8,000
Flagstaff Fire Dept Fuels Reduction	125	2,000
Forest Products Residuals	N/A	45,000
TOTALS	**11,280**	**225,480**

Urban Wood Waste

Wood waste generated by tree service companies, local residents, and businesses in the FSA regularly generate wood waste in the form of tree trimmings, construction debris and demolition wood. Known as urban wood waste, much of this wood waste generated within the FSA is currently deposited at the Cinder Lake Landfill located just northeast of Flagstaff.

Wood Waste Generated Within Flagstaff

The city of Flagstaff manages the Cinder Lake Landfill. Discussions with landfill staff[70] indicated that the landfill currently receives significant volumes of wood waste in the form of green waste (e.g., tree trimmings) and wood waste (e.g., construction wood). From 2012 through 2017 (most recent data available), annual wood waste received ranged from 821 green tons (GT) in 2012 to 3,668 GT in 2017. Historically, wood waste volume received at the landfill has been variable based on general economic conditions in the region. As the economy has rebounded and residential construction has increased, so too has wood waste volume delivered to the landfill. Average volume of wood waste for the last five years has been 2,393 GT/year. Assuming 25% moisture content, this amounts to 1,795 BDT/year.

[69] Based on interviews with resource managers and logging contractors operating in northern Arizona.
[70] Matt Morales, Senior Project Manager, Cinder Lake Landfill.

Like many landfills, Cinder Lake Landfill is grinding green waste and wood waste onsite and using this material as alternative daily cover (ADC). As the term implies, the processed woody material is used to cover the landfill on a daily basis with a layer of ADC between 6" and 12" deep to control odor and vermin. Landfill staff noted that using tarps to cover the landfill on a daily basis is an alternative that could be considered if the value of processed urban wood delivered to Camp Navajo would justify such a change in operations. TSS estimates that between $25 and $30 per BDT would be required to address all of the urban wood handling, processing, and transport costs for delivery to Camp Navajo.

Wood Waste Generated Within Camp Navajo

Discussions with Garrison Commander Colonel Garcia confirmed that very little wood waste is generated onsite at Camp Navajo.

Wood Waste Generated Within Williams

Discussions with Williams Transfer Station staff[71] confirmed that between 75 and 105 GT of wood waste is received annually. Assuming 25% moisture content, this amounts to between 56 and 79 BDT/year. Most of this material is made up of tree trimmings and construction wood. Currently, much of this material is piled and burned onsite. Staff confirmed that diverting this material to Camp Navajo for use as bioenergy feedstock is a much preferred alternative. There is strong motivation to seek an alternative to open burning as the primary disposal method at the transfer station.

Findings

Urban wood waste from the Cinder Lake Landfill and Williams Transfer Station amounts to approximately 1,862 BDT/year. For the purposes of this analysis, TSS assumes all of this wood waste would be available as feedstock for a bioenergy facility at Camp Navajo.

Pinyon-Juniper Grassland Restoration

The vast majority of grassland restoration initiatives within northern Arizona are focused on the removal of juniper trees within the PJ vegetation type. PJ dominated landscape within the Camp Navajo FSA totals 917,886 acres, amounting to 18% of the FSA. The extensive acreage of PJ within the FSA represents the second most significant source of woody biomass material (behind forest cover type). However, simply considering the acreage covered by this vegetation type is not enough. The low volumes of biomass per acre, the slow growth rates, and the wide variation in shape and size of the trees make it a difficult woody biomass source to assess. In the PJ vegetation cover type, it is the juniper tree species that are targeted for removal. Pinyon pine trees are valued for their wildlife habitat features (e.g., Pinyon jay population habitat). In northern Arizona there are three types of juniper that range conservationists are selecting for removal: alligator juniper, Utah juniper, and one-seed juniper. For the purposes of this analysis, all three juniper species are lumped together and referenced as PJ material. A major focus of juniper removal is wildlife habitat improvement and grassland restoration (mule deer, prong horn, commercial livestock).

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[71] Jeff Pettit, Site Supervisor, Williams Transfer Station.

Juniper tree species have not traditionally been utilized by the wood products industry. Forestry research on their abundance and distribution, and on attributes such as density (e.g., number of stems per acre) or volume (e.g., aboveground biomass), have only recently become of interest. Within the last few decades, range managers and conservationists have sought to return juniper stocking levels to more natural conditions by reducing existing stocking levels. The widescale suppression of wildfire and domestic livestock grazing has allowed juniper to proliferate, and this in turn has caused grasslands to be degraded due to the high water and nutrient uptake of young juniper stems. Water and nutrient availability within the arid grassland ecosystem of northern Arizona can significantly impact desirable vegetation such as grass and herbs favored by wildlife and commercial livestock. Removing unnatural concentrations of juniper stems will free up water and nutrients for more desirable forage.

Previous work conducted by TSS within northern Arizona as well as recent discussions with range managers[72] in Coconino County confirmed desirable removal rates for juniper at between 4.7 and 10.6 BDT/acre. For the purposes of this analysis, TSS utilized an average removal rate of 7.65 BDT/acre.

US Forest Service

The USFS manages approximately 701,132 acres (76%) of PJ vegetation type within the Camp Navajo FSA. Discussions with USFS staff[73] confirmed that the Kaibab National Forest has been actively restoring PJ grasslands by felling and leaving juniper stems (as there is no current market for PJ stems) at the rate of 2,500 to 3,500 acres/year. Current treatments are conducted by USFS staff using two skid steer machines equipped with shears. Juniper stems are left onsite and could be available for collection and processing. Between 10,000 and 15,000 acres of treated area could be available for removal of felled juniper stems. Road infrastructure conditions are variable and will likely require investment to meet chip truck transport standards.

USFS staff noted that the Kaibab National Forest Land Management Plan has a PJ grasslands restoration treatment goal of 5,000 to 10,000 acres/year. The level of future restoration treatments will depend on funding availability to complete NEPA analysis and pay for treatment activities. Past PJ restoration efforts have received funding support from a variety of entities including the Arizona Elk Society, Rocky Mountain Elk Foundation, Natural Resource Conservation Service, and the Arizona Game and Fish Department. USFS staff forecast about 5,000 acres/year of PJ restoration treatments within the FSA over the next 10 years.

State Lands

Arizona State Lands Department (ASLD) manages approximately 77,237 acres (8%) of PJ vegetation cover within the Camp Navajo FSA. Discussions with ASLD staff[74] confirmed a high level of interest in accelerated treatment of PJ grasslands. Historically, 2,000 to 4,000 acres are treated annually using mostly fall and leave technique (similar to USFS) with some mastication.[75] There are thousands of acres of juniper stems, many of which have road access

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[72] Chris Lowman, Range Section Manager, Arizona State Lands Department.
[73] Roger Joos, Wildlife Biologist, Williams Ranger District.
[74] Chris Lowman, Range Section Manager, Arizona State Lands Department.
[75] Mastication is mechanical grinding of vegetative material onsite.

and could be collected, processed and removed. Much of the current PJ restoration efforts are coordinated with nearby ranches[76] that hold grazing leases (typically 10 to 20 years in duration) with the ASLD.

Because these acres are considered State Trust lands, there is an expectation that revenue is generated if any product is removed. Current juniper removals by Tri-Star Logging in Eastern Arizona are being levied a $0.26/BDT stumpage rate based on an appraisal conducted by the ASLD. In addition, an archeological survey is required before land management activities can proceed. Arch surveys typically cost $50 to $100/acre. Past PJ restoration efforts have received funding support from a variety of entities (Arizona Elk Society, Rocky Mountain Elk Foundation, Natural Resource Conservation Service, Arizona Game and Fish Department). This funding support is likely to continue. ASLD staff forecast about 7,000 acres per year of PJ restoration treatments within the FSA over the next 10 years.

Private Ranches

Private lands include approximately 122,010 acres (13%) of PJ vegetation type within the Camp Navajo FSA. The Natural Resources Conservation Service (NRCS) and Arizona State Game and Fish Department work with ranches in northern Arizona to promote PJ grassland restoration as part of the Regional Conservation Partnership Program. NRCS deploys range specialists that provide technical assistance to area ranchers who manage their own lands and in many cases, also hold permits or leases on federal and state lands. The NRCS range specialists are available to help ranchers with management plans addressing soil, water, plants and animals with a focus on managing the grasslands towards a restored condition using ecological site descriptions as benchmarks.

NRCS support through the Environmental Quality Incentives Program (EQIP) provides cost share funding to support range restoration (and other site improvement activities). Cost share rates for juniper treatments currently range from $103 to $233/acre. EQIP funding is dependent upon annual appropriations as directed by Congress. Alternative funding to support PJ grassland restoration is potentially available from a variety of other entities (Arizona Elk Society, Rocky Mountain Elk Foundation).

If EQIP cost share funding (or other funding sources) is available, coupled with a ready market at Camp Navajo for processed juniper material, TSS anticipates that ranch managers will be highly interested in actively conducting PJ restoration activities on private ranches within the FSA. TSS forecasts PJ restoration efforts on private ranches to be similar to the ASLD forecast at 7,000 acres/year.

Findings

Summarized in Table 10 are TSS findings regarding residuals generated from PJ restoration activities. A recovery factor of 7.65 BDT/acre[77] was utilized to calculate juniper material volume produced annually.

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[76] Ranches currently holding grazing leases include Perrin Ranch, McNelly Ranch and Babbitt Ranch.

[77] Previous work conducted by TSS within northern Arizona as well as recent discussions with range managers confirmed desirable removal rates for juniper at between 4.7 and 10.6 BDT per acre for an average removal rate of 7.65 BDT per acre.

Table 10. Potentially Available PJ Grassland Restoration Residuals

OWNERSHIP	ACRES TREATED/ YEAR	POTENTIAL VOLUME AVAILABLE (BDT)
US Forest Service	5,000	38,250
State Lands	7,000	53,550
Private Ranches	7,000	53,550
TOTALS	**19,000**	**145,350**

Feedstock Competition Analysis

Current Competition

Currently, there are relatively few markets for wood waste material generated within the Camp Navajo FSA. Summarized in Table 11 are observations regarding current markets for wood waste by feedstock type.

Table 11. Current Markets for Biomass Feedstock

FEEDSTOCK	CURRENT MARKETS
Forest Operations Residuals	Gro Well Brands at Phoenix: Landscape cover and mulch.
	Scotts Miracle Gro at Maricopa: Landscape cover and mulch.
	Novo BioPower at Snowflake: Biomass fuel for power generation.
	Flagstaff area mulch market.
Forest Product Residuals	Animal bedding – bagged or delivered in bulk.
	Gro Well Brands at Phoenix: Landscape cover and mulch.
	Scotts Miracle Gro at Maricopa: Landscape cover and mulch.
	Novo BioPower at Snowflake: Biomass fuel for power generation.
	Onsite use as hog fuel for lumber kilns.
PJ Restoration Residuals	Novo BioPower at Snowflake: Biomass fuel for power generation.
Urban Wood Waste	Alternative Daily Cover

Note that the current markets for forest operations residuals, forest product residuals, and PJ restoration residuals are all located some distance from Camp Navajo (130 to 187 miles one-way). There is incidental Flagstaff area market demand for forest residuals (processed slash) as mulch,[78] but this should not exceed 100 to 150 BDT/year. A biomass power generation facility at Camp Navajo would have a significant transportation cost advantage over current markets.

Future Competition

TSS is not aware of any future plans to develop commercial-scale wood utilization enterprises within or adjacent to Camp Navajo.

[78] Per discussions with High Desert Investments.

There will likely be reduced market competition from the Novo BioPower facility, as their current power purchase agreement (PPA) with Arizona Public Service (APS) terminates in 2023. A 2017 report[79] commissioned by APS confirmed the utility has no interest in extending the current PPA with Novo BioPower.

Potential Competition

A variety of ventures have been considered that could source wood waste from the Camp Navajo FSA. None have announced plans to commence site acquisition or environmental permitting.

Findings

Current markets for processed wood waste material are located some distance (130 to 187 miles one-way transport distance) from Camp Navajo. Interviews with land managers and forest residual processors confirm that delivered prices offered for forest and PJ residuals provide enough compensation to only address transportation costs. In some cases, wood feedstock suppliers must subsidize transport costs, as delivered prices are quite low. In addition, the landscape and mulch market prices can be inconsistent and market demand seasonal.
TSS is not aware of any active plans to develop commercial-scale enterprises that might constitute potential competition for wood waste feedstock within or adjacent to the Camp Navajo FSA. A biomass power generation facility at Camp Navajo would have a significant transportation cost advantage over current markets.

Feedstock Supply Availability Findings

Summarized in Table 12 are feedstock supply availability findings. Note that these findings are presented as potentially available, technically available, and economically available. The potentially available volume is the total amount of biomass feedstock that could be available annually if no constraints existed. Recoverable biomass is judged to be technically available considering physical constraints (such as terrain and transport) and regulatory policy constraints. Economically available biomass is the amount technically available considering existing competition for wood waste material. At this time, there is very little competition for biomass feedstocks within the Camp Navajo FSA.

Table 12. Feedstock Supply Availability Within the FSA

FEEDSTOCK	POTENTIALLY AVAILABLE BDT/YEAR	TECHNICALLY AVAILABLE BDT/YEAR	ECONOMICALLY AVAILABLE BDT/YEAR
Forest Operations Residuals	180,480	162,432	162,432
Forest Products Residuals	45,000	45,000	42,750
Urban Wood Waste	1,850	1,850	1,850
PJ Restoration Residuals	145,350	123,548	123,548
TOTALS	**372,680**	**332,830**	**330,580**

Assumptions used to generate Table 12 are as follows:

[79] APS Forest Bioenergy Report, Black and Veatch, November 2017.

- Forest operations are conducted primarily on federal, state and private lands with road systems that will support removal of forest biomass material across 90% of the acres treated, thus reducing potentially available volume by 10% to calculate technically available volume. In addition, USFS managed land available for mechanical treatments (including biomass removal) is reduced by 182,733 acres due to wilderness designation within the Camp Navajo FSA.

- PJ restoration activities are conducted on federal, state and private lands with road systems that will support removal of juniper biomass material across 85% of the acres treated, thus reducing potentially available volume by 15% to calculate technically available volume.

- Forest products residuals technically available volume is reduced by 5% to address local mulch, landscape and animal bedding markets and calculate economically available volume.

Transportation Infrastructure

Camp Navajo

As noted earlier (see Site Conditions Analysis), Camp Navajo has ready access to the BNSF railway. Discussions with a BNSF representative[80] confirmed that the BNSF rail line bordering the northern boundary of Camp Navajo is the busiest track within the railway's system. Ports served directly include Port of Stockton, Port of Long Beach, and Port of Los Angeles. Multiple rail spurs on Camp Navajo provide ready rail access.

Commercial truck access (also discussed in the Site Conditions Analysis) is available via I-40. Camp Navajo and Coconino County are in discussions with Arizona Department of Transportation (ADOT) to upgrade the existing overpass by adding additional lanes.

State regulations stipulate an 80,000 pound gross vehicle limit. Commercial chip trucks typically weigh 30,000 pounds empty (tare weight) with ability to transport 50,000 pounds of cargo (net weight). ADOT offers a variance to this weight limit allowing the transport of 90,800 pounds of forest-derived fuel as part of the Healthy Forest Initiative. However, this variance only applies to state highways and does not impact a project at Camp Navajo as the primary transport route includes a federal interstate (I-40).

There is a significant road system in place at Camp Navajo due to the long history of commercial timber harvest and military training operations. Discussions with logging contractors that have conducted operations within Camp Navajo confirmed a road system that can accommodate chip trucks, occasionally with some improvement to road alignment to allow passage of 40 to 50 foot length trailers.

[80] Jared Garmon, Industrial Product Business Development, BNSF.

US Forest Service

TSS conducted interviews with resource managers and logging contractors operating in northern Arizona on USFS managed lands. Most of the forest areas targeted for commercial timber operations are well roaded; however, many of the existing roads have not been maintained and require improvements (grading and road realignment) to facilitate chip trucks. Roads across PJ grasslands will need significant improvement to accommodate commercial truck traffic.

State and Private Lands

Roads systems on state and private lands are quite variable due to inconsistent use over time. Due to the relatively poor market conditions for sawlogs and wood fiber, there has been very little need to maintain road systems.

Findings

Transportation infrastructure in the region adjacent to Camp Navajo is made up of rail transport served by the BNSF railway and a road transport system comprised of a significant interstate (I-40), state, county and private roads. The BNSF tracks are the railway's busiest mainline and serve major West Coast ports.

Road access to Camp Navajo is primarily via I-40 with discussions currently underway with ADOT to improve the existing highway overpass. The forest road system within Camp Navajo is extensive and will facilitate chip trucks.

The forest road system within the region is robust on USFS managed lands due to a long history of forest management. Road systems in the PJ cover type are not well developed. Road systems on private and state lands are variable depending on the degree of active management. Due to ADOT weight limit requirements (80,000 pound gross vehicle weight), commercial trucks can accommodate about 50,000 pounds of cargo (25 GT).

Characterization of Biomass Feedstocks

Urban Wood Waste

Urban wood waste is made up of green waste (e.g., tree trimmings, grass clippings, pine needles) industrial wood (e.g., pallets), and construction/demolition (C&D) wood. Green waste is typically sorted and processed for use as soil amendment. Industrial wood and C&D wood can be sorted for processing of clean, contaminate-free wood. This relatively clean wood is then processed for use as urban wood waste fuel.

Tree Species

<u>Pine/Fir/Mixed Conifer</u>

The predominant tree species in the pine/fir/mixed conifer vegetation cover type is ponderosa pine. Some true fir and Douglas-fir co-exist with ponderosa pine at higher elevations.

Pinyon-Juniper

The predominant tree species in the pinyon-juniper vegetation cover type is juniper. As an invasive tree species, range managers select juniper for removal and tend to leave the pinyon pine due to wildlife habitat attributes.

Feedstock Characteristics

Summarized in Table 13 is the feedstock characterization summary. These characteristics are based on TSS' experience with feedstocks sourced from commercial operations and utilized as biomass fuel.

Table 13. Feedstock Characteristics

KEY CHARACTERISTIC	FOREST RESIDUALS	JUNIPER	URBAN WOOD WASTE	SAWMILL RESIDUALS
Moisture Content (% moisture)	30% to 45%	25% to 40%	15% to 30%	35% to 50%
High Heat Value (Btu/dry pound)	8,000 to 8,800	8,000 to 8,700	7,500 to 8,000	8,000 to 8,500
Ash Content (% by dry weight)	3% to 5%	4% to 8%	4% to 12%	3% to 5%

Chip Characteristics

Forest residuals have potential value as feedstock (also known as furnish) for composite panel operations (e.g., particleboard or hardboard). Composite panel operations prefer low ash and low bark content feedstock and typically require forest-based operations to remove bark before chipping in the woods. This requires a flail (typically a chain flail) be set up ahead of the chipper, thus adding $12 to $15/BDT additional cost. Sawmill residuals such as planer shavings and chips are excellent feedstock for composite panels due to very consistent quality. Juniper or urban wood waste are not considered desirable feedstocks due to inconsistent overall quality (chip size, moisture content, ash content).

Feedstock Supply Cost Analysis

Costs to Collect, Process and Transport Biomass Feedstocks

Logging contractors are currently providing processed biomass material to the Novo BioPower facility and commercial landscape product operations in Phoenix[81] and Maricopa.[82] TSS conducted interviews with a variety of contractors managing biomass collection, processing and transport operations within the Camp Navajo FSA. Results of the interviews and TSS past experience and knowledge of biomass operations were used to analyze these costs.

Feedstock Transport Costs

[81] Gro-Well Brands, Inc. https://www.gro-well.com/
[82] Scotts Miracle-Gro Company https://scottsmiraclegro.com/

Biomass transport costs typically represent the most significant cost center and are summarized in Table 14, addressing each of the radii that make up the FSA.

Table 14. Feedstock Transportation Costs

FEEDSTOCK SOURCING AREA RADII	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)
20 mile (40 to 50 mile round trip distance)	$14.96	$16.74
30 mile (60 to 70 mile round trip distance)	$18.53	$20.31
40 mile (80 to 90 mile round trip distance)	$22.10	$23.88
50 mile (100 to 110 mile round trip distance)	$25.67	$27.46

Assumptions used to calculate the range of costs summarized in Table 14:

- Transport costs are calculated on a round trip distance basis.
- Forest biomass removal operations follow commercial harvest operations.[83]
- Average transport speed is 35 miles/hour.
- Load time is 45 minutes.
- Unload time is 30 minutes.
- Haul costs are $100/hour using conventional chip truck trailer.
- Forest and PJ biomass material average 16 BDT/load (net weight).
- High range is an additional 10 miles round trip distance.

Feedstock Collection, Processing and Transport Costs

Considering the full range of costs (collection, processing and transport), Table 15 provides results of the cost analysis (low and high range).

Table 15. Feedstock Delivered Cost Forecast 2020 Through 2025 by Feedstock Type

FEEDSTOCK TYPE	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)
Forest Operations Residuals	$39.96	$63.46
Forest Products Manufacturing Residuals	$20.00	$30.00
PJ Grasslands Restoration	$34.97	$43.72
Urban Wood Waste	$24.96	$29.96

Assumptions used to calculate range of costs summarized in Table 15:

- Service fees or cost share are available from public agencies to offset the cost of collection, processing, and transport of PJ grassland restoration residuals. Cost estimates are reduced by 30% to reflect this cost share.
- Low range for forest operations residuals and PJ grassland restoration residuals assumes one-way haul distance of 20 miles (40 miles round trip).

[83] Thus, much of the timber harvest residuals (limbs, tops, small stems) are piled roadside at the landing.

- High range for forest operations residuals and PJ grassland restoration residuals assumes one-way haul distance of 50 miles (100 miles round trip).
- Forest biomass is collected and processed into truck (at the roadside landing) for $25 to $36/BDT.[84]
- Haul costs are $100/hour using conventional chip truck trailer.
- PJ restoration residuals are collected and processed into truck (at the roadside landing) for $35 to $45 per BDT[85](pre-cost share contribution).
- Forest products residuals pricing is market driven and not associated with collection and processing (unlike forest operations and PJ grassland restoration residuals).
- Forest products residuals are available within a 30 mile one-way haul distance (60 miles round trip).
- Biomass material averages 16 BDT/truckload (net weight).

Findings

The cost to collect, process and transport forest operation residuals sourced from Camp Navajo would be approximately $44.56/BDT. This estimate assumes a 10 mile one-way haul distance and an average travel speed of 20 miles/hour (to account for travel along forest road system). On the upper range of transport distance (assuming a 20 mile one-way distance) the cost to collect, process, and transport forest residuals is $50.81/BDT.

Forest operations residuals and PJ grassland restoration residuals represent the most significant feedstock types. Service fees are potentially available to support PJ grassland restoration through ongoing programs managed by NRCS and the State Game and Fish. Transport costs are the most significant variable impacting cost.

Five-Year Feedstock Cost Forecast

Optimized Feedstock Blend

Summarized in Table 16 is the optimized fuel blend forecast for a bioenergy facility scaled at 20 MW of power generation.

Table 16. Optimized Fuel Blend Forecast

FEEDSTOCK TYPE	DELIVERED PRICE ($/BDT)	ANNUAL VOLUME (BDT)	COST
Forest Operations	$51.71	75,000	$3,877,901
Forest Product Residuals	$25.00	35,000	$875,000
PJ Restoration	$39.34	48,150	$1,894,401
Urban Wood Waste	$27.46	1,850	$50,792
	TOTALS	160,000	$6,698,095
	BLENDED PRICE	**$41.86**	

[84] Most of the forest biomass residuals are left at the roadside landing, available for processing.
[85] PJ material collection and processing costs are higher than forest material collection and processing costs due to the fact that PJ material is less concentrated (fewer BDT/acre) than forest biomass material.

Approximately 4,700 acres of forest operations are required to produce 75,000 BDT/year of fuel. Approximately 6,300 acres of PJ grassland restoration are required to produce 48,150 BDT/year of fuel.

Note that the delivered price estimate in Table 16 is extracted from Table 15 as a mid-range figure between low and high range feedstock cost estimate.

Five-Year Feedstock Cost Forecast

Summarized in Table 17 is the five-year feedstock cost forecast for feedstock delivered to Camp Navajo.

Table 17. Delivered Feedstock Cost Forecast 2020 to 2024

YEAR	2020	2021	2022	2023	2024
DELIVERED COST ($/BDT)	$41.86	$42.49	$43.13	$43.78	$44.43

Assumptions used to calculate range of costs summarized in Table 17 are as follows:

- The bioenergy facility is scaled at 20 MW of power generation.
- The optimized feedstock blend as shown in Table 16 is maintained over all five years.
- 2020 feedstock pricing is based on blended feedstock cost shown in Table 16.
- Diesel fuel and labor costs increase year to year which cause delivered feedstock costs to increase 1.5% year over year.

Feedstock Supply Risks

Time of Year Availability

Discussions with contractors and resource managers confirmed that collection and processing operations within forest and PJ cover types are conducted eight to nine months per year. Winter weather can impact field operations between late December and early April. In addition, high fire danger conditions during summer months can require field operation curtailment. Considering the potential for fuel deliveries from forest operations and PJ restoration activities not being available three to four months per year, a commercial-scale biomass power facility at Camp Navajo should have the ability to inventory at least 90 days of fuel onsite.

Changes in State or Federal Policies

<u>State Policies</u>

On November 19, 2018, the Arizona Corporations Commission (ACC) held a forest bioenergy stakeholder meeting. A number of entities presented the case for an active forest bioenergy sector in Arizona, including Coconino County, USFS, 4FRI Stakeholders Group, Novo Biopower, and the Ratepayer Utility Consumer Office. Several of the ACC commissioners in attendance[86] suggested that the Arizona state legislature should take a more active role and legislate financial support for the forest bioenergy sector as a cost share arrangement so that the taxpayers as well as the ratepayers share above market power generation costs. ACC staff encouraged written input regarding need for a forest bioenergy sector. Staff will then draft an ACC proposal for consideration at the December 10, 2019 forest bioenergy stakeholder meeting.

Federal Policies

In March 2018, the President signed into law the Consolidated Appropriations Act (H.R. 1625) which included congressional direction and emphasis regarding the importance of forest bioenergy. In response to HR 1625, the US EPA, U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (US DOE) are working collaboratively to:

- Ensure that federal policy relating to forest bioenergy is consistent across all federal agencies and recognize the full benefits of forest biomass utilization.
- Establish clear and simple policies that reflect the carbon beneficial status of forest bioenergy.
- Encourage private investment throughout the forest biomass supply chain.

On October 24, 2018, a letter jointly signed by all three agencies (US EPA, USDA, US DOE) was submitted to congress confirming the agencies' commitment to expand the use of forest bioenergy (Appendix A).

A federal renewable energy standard has been considered in the past. However, there will likely be little movement in the near term as Congress appears ready to let the states determine renewable energy policies specific to regional resources and goals.

Considering the extreme nature of the 2018 wildfire season, there will likely be strong consideration for increased federal funding to support fuels reduction within the Inland West.

Sawmill Infrastructure

In the near term, it will be critical that a robust commercial-scale forest products sector be developed within the Camp Navajo FSA. While there have been several attempts (e.g., Newpac Fibre, Grand Canyon Forest Products) to develop small log sawmills near Williams, none have been financially successful. Recent efforts by NewLife Forest Products and Perkins Forest Products appear promising. Long-term forest feedstock supply availability (forest operations and forest products residuals) rely on a ready market for sawlogs.

Observations Regarding Feedstock Supply at 5, 10, and 20 Years

As noted above, the long-term prognosis for two key feedstocks – forest operation residuals and forest products residuals – are very dependent upon a robust commercial-scale forest products manufacturing sector. Land management agencies such as the USFS, NRCS, ADFFM, and ASLD are highly motivated and focused on the long-term health and fire resiliency of forest and grassland ecosystems in northern Arizona. In addition, key electrical utilities such as Salt River

[86] Commissioners Burns and Olson.

Project are highly interested in healthy upland watersheds (particularly the Verde River and Salt River watersheds) within the region.

Future feedstock supply availability will be very dependent upon a robust forest products manufacturing sector.

Additional Biomass Power Infrastructure

Arizona Public Service (APS) and Salt River Project (SRP) have issued Request for Proposals (RFP) for bioenergy generation within Arizona (see Appendix B and C). Unfortunately, it appears that APS has abandoned this effort. It is unclear if the SRP RFP will result in the siting of a commercial-scale biomass power plant. If a project is developed within or tributary to the Camp Navajo FSA, it could impact feedstock supply availability and pricing.

Optimized Scale for Wood To Energy Facility

For bioenergy project financing, a fuel feedstock supply coverage ratio of 2:1 is typically preferred. The private financial markets are very risk averse, and feedstock supply is considered a critical factor in the long-term financial viability of a bioenergy facility. Based on the feedstock supply availability findings of 330,580 BDT/year (see Table 12), there is sufficient coverage for a bioenergy facility with 20 MW (net generation) capacity.[87]

If a bioenergy facility at Camp Navajo secures debt financing that does not require a 2:1 feedstock coverage ratio, there is enough sustainably available feedstock to support a bioenergy facility scaled at 40 MW (net generation) capacity. TSS assumes that debt financing will likely be necessary, so the 20 MW scale was utilized for the purpose of this analysis.

WOOD TO ENERGY TECHNOLOGY EVALUATION

There are several mature technologies available to produce electricity utilizing the available biomass feedstock supply. The relatively low moisture content (15% to 45%) of available fuel feedstocks within the Camp Navajo FSA provides a distinct advantage. Drier feedstocks allow the facility to operate at higher efficiencies because fuel moisture is the most significant source of boiler inefficiency in the combustion of biomass. Also, the feedstock supply assessment noted that available feedstocks have a relatively low ash content (3% to 5%). This range of feedstock moisture content and relatively low ash content allows the widest selection of technology to be used without being limited due to technological restrictions on moisture or non-combustible content.

Technological Review

The economic drivers of a biomass project located on Camp Navajo require the plant to have a high degree of confidence in its successful long-term commercial operation at predicted operating capacity. Too often, biomass energy projects fail due to application of technologies which have not been sufficiently proven at commercial-scale, which cause delayed

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[87] A commercial-scale bioenergy facility utilizes approximately 8,000 BDT/MW of generation capacity. A 20 MW facility will utilize about 160,000 BDT of woody biomass per year.

commissioning, inability to meet annual availability at 100% capacity, and unexpected equipment maintenance or failures. The main drawback of cutting-edge biomass energy technologies is lack of economic performance for commercial-scale applications because of a power plant's economic necessity for 95% or higher availability at 100% generating capacity. Even technologies with moderate reliability are downgraded because the risk is greater than the reward. The larger the scale of the facility, the plant economics become increasingly less forgiving. This evaluation focuses solely on technologies which have been commercially proven at the highest reliability and at the optimum scale given all considerations for this site.

There are two classes of commercially proven technologies that fit the availability criteria: direct combustion and gasification. A subset of the gasification technology uses a gasifier to produce low Btu gas to power an internal combustion engine (ICE). Any commercially operating example of this technology is in small modules of approximately one MW or less; this precludes the gasification-ICE option for Camp Navajo due to the increased costs associated with economies of scale.

Direct Combustion

Direct combustion is the original form of biomass to energy technology and therefore has the highest number of operating biomass to electric power plants currently in commercial service. Direct combustion uses a furnace with a grate (one of various kinds of grates) which support the biomass and allow over fire and under fire air to facilitate efficient combustion with the average air content of the furnace between 35% and 80% excess to burn the biomass fuel. Several different options exist in grate style[88] but all operate using the same type of combustion.

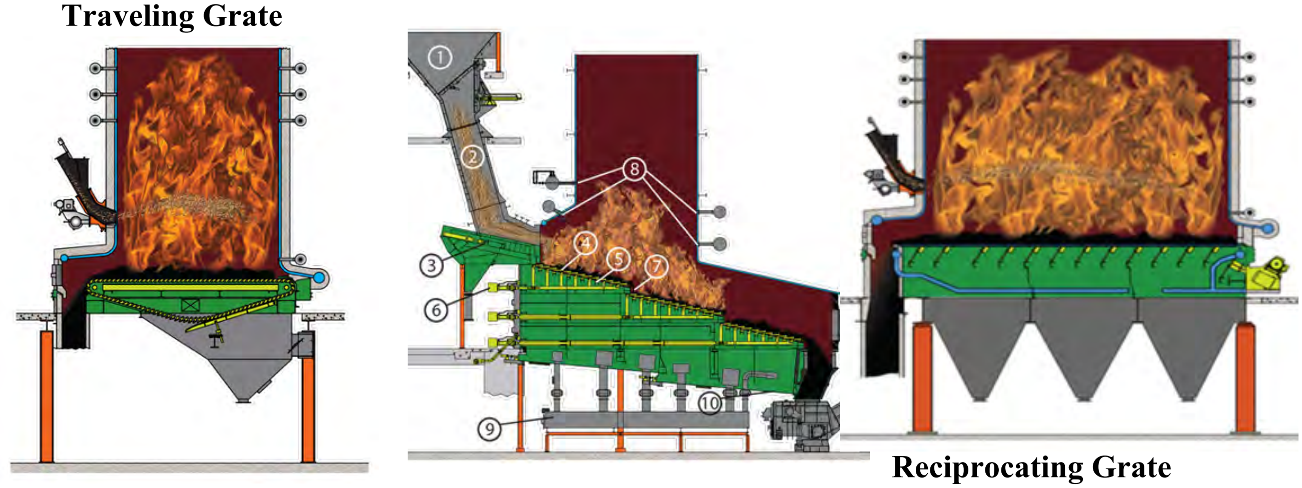
Stoker

Highly mature, with many units worldwide in excess of 50 MW generation capacity, stoker boilers were first used for woody biomass combustion in the 1940s. These units were originally designed to combust coal and are a relatively basic technology. Variations include fixed grate, travelling grate, and reciprocating/vibrating grate. Fixed or stationary grate technology has a critical flaw relating to power production due to the need to manually de-ash the furnace, which requires a significant portion of the furnace to be taken offline. Travelling grates and vibrating grates are both capable of mechanical ash removal with no reductions to generation capacity. They can operate on a variety of biomass fuels but operate best while burning 3" diameter or smaller biomass which does not exceed 50% moisture content. Typically, stokers utilize pneumatic spreaders to distribute the fuel evenly onto the grate. This can cause small wood particulates to be carried by the upward velocity of air, thus not allowing complete combustion. This results in higher unburnt carbon content of the ash generated by the plant, typically around 3.5% (by weight).

[88] Travelling grate, vibrating grate, inclined grate.

Figure 22. Stoker Combustor Technologies

Traveling Grate



Reciprocating Grate

Vibrating Grate

Images are courtesy of Detroit Stoker Company

<u>Fluidized Bed</u>

Also a mature commercially deployed technology, fluidized bed boilers were developed in the 1980s to facilitate more complete combustion of a wide range of feedstocks. A fluidized bed uses free flowing sand-like medium and evenly distributed air to mix both the fuel and the bed material in the combustion zone. The two types of equipment available include bubbling fluid beds and circulating fluid beds. Bubbling fluid beds (BFB) operate with all the bed material remaining in the area, above and around the air distribution nozzles, and are usually deployed in the 10 MW to 30 MW capacity scale. Circulating fluid beds (CFB) have higher air velocities, which convey both the fuel and the bed material vertically through the furnace until the bed material is captured in a vortex breaker and recycled. Both fluidized bed technologies excel at burning high moisture (up to 70% wet basis) and high ash (up to 30% inert material) fuels,[89] but have slightly higher station load power requirements than stoker systems. Due to the controlled temperatures within either CFB or BFB furnaces, a very high fuel combustion rate is achieved. Ash from CFB or BFB boilers has unburnt carbon contents of 1% by dry weight or less, representing a slight fuel efficiency advantage compared to stoker boilers. A diagram demonstrating the difference between bubbling bed and circulating bed is provided in Figure 2.[90]

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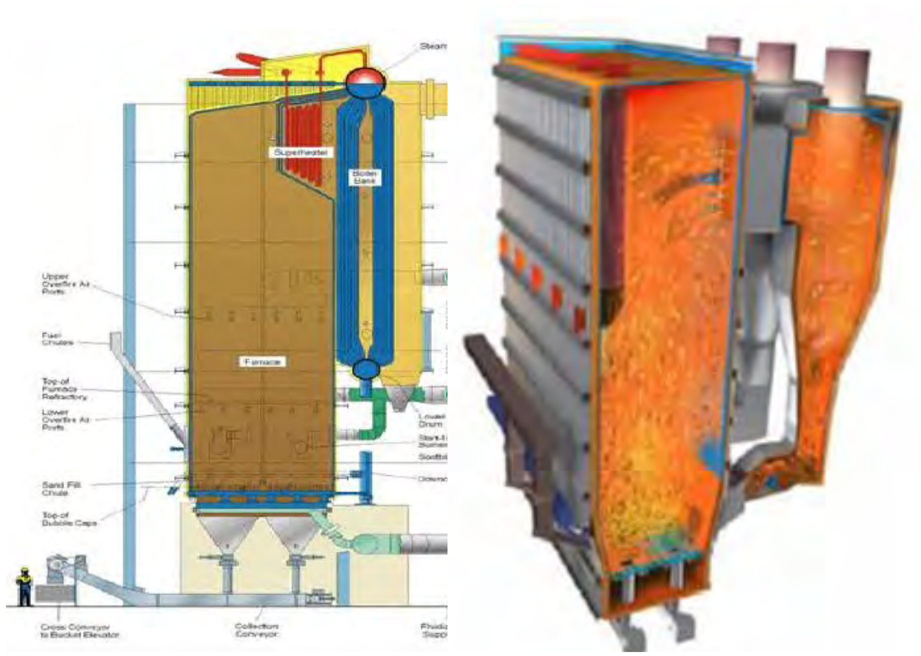
[89] Environmental Protection Agency (2003) AP 42, Fifth Edition Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources. Section 1.6-1.

[90] Courtesy of Babcock Power Generation Group.

Figure 23: **Fluidized Bed Boiler Technologies**



Bubbling Fluid Bed **Circulating Fluid Bed**

Images are courtesy of Amec Foster Wheeler Company

CFBs have been commercially deployed at a range of scales from 30 MW to as high as 460 MW[91] with most combusting coal. Due to CFBs slightly higher capital cost, 30 MW is typically the smallest CFB built for electric power generation. This technology has been widely used in California for their ability to utilize a variety of wood fuels. Fluidized bed technology is newer, more complex and requires slightly more station power, but it offers more flexibility in fuels used and operating control. In addition, fluidized bed systems offer significant flexibility because they can operate under a wide range of load conditions and typically have a lower air emissions profile due to lower operating temperatures.

Gasification

Gasification is defined as the heating of feedstock material in the absence of oxygen, which produces a low Btu gas stream that varies between 5% and 25% the energy of natural gas/cubic foot.

<u>Gasification to Steam Cycle</u>

The mature form of this technology is the gasification to steam cycle, or close coupled gasification. The majority of gasification technologies operate in the pyrolysis temperature range (400 to 900 degrees F) and produce a gas stream containing high amounts of carbon monoxide and hydrogen, with small fractions of tars, heavy pyrolysis oils, particulate and ash. These gasification products require minimal cleaning and can be directly burned in a close-coupled oxidizing (combustion) chamber to release all the energy for recovery by the steam

[91] Lagisza Power Plant in Poland.

cycle boiler. Outotec (formerly Energy Products of Idaho) gasifiers are a subset of bubbling fluidized bed boiler systems and are capable of operating as gasifiers.

A good example of this is the 10 MW Birmingham Bio Power Plant deployed in 2016 at Birmingham, UK. The Birmingham plant follows this gasifier/oxidizer model with an all in cost of approximately $60 million US ($6,000,000/MW of capacity). This capital cost falls on the highest end of the gasification capital cost range presented later in this section. By comparison, this capital cost is more than two times that estimated for stoker grate power plants.

Although this technology has been around for a long time, it is not considered fully commercialized (not market mature). There are a handful of operating biomass gasification systems in the U.S. and many of these are partially government-funded demonstration units.

Gasification to Internal Combustion Engine Genset

This technology converts woody biomass to a syngas, which is then delivered to an internal combustion engine (ICE) genset. It is critical that the ICE engine be modified to burn low Btu syngas. Due to potential fouling by tars and abrasion by particulate, the syngas must be highly cleaned by scrubbers and/or wet electrostatic precipitators before delivery to the ICE engines. This requires that the syngas be cooled from the 1,000 to 1,200 degrees F to an approximate temperature of 250 degrees F for the gas cleanup equipment to function. This creates a large thermal inefficiency of the system, which puts it at a disadvantage compared to direct combustion via stoker or fluidized bed.

Environmental Permitting

Permitting for a woody to electrical energy facility is discussed in detail in the Energy Information, Incentives, and Permitting section. In summary, a biomass power plant on Camp Navajo or in the Bellemont industrial area could require a Class 1 air permit from the ADEQ, along with a Title V permit (additional analysis and discussion can be found in the Potential Environmental Impacts section below). The power plant could require a water quality permit if a lined impoundment is needed, which could be necessary if direct combustion technology is used. Storm water permits for both construction and operation would be required at both sites. If the biomass power plant is sited in the Bellemont industrial area, a CUP would be necessary from Coconino County.

Water Consumption and Discharge

The largest consumer of water in a power plant is typically from condensing the steam exhaust from the turbine. There are three ways generally accepted in utility scale power plants to reject this heat from condensation to the environment: once through cooling, open loop cooling (evaporative cooling tower), and closed loop (air cooled).

Once through cooling uses a high volume of water to absorb the necessary heat and reinjects it to the source, typically a river or large body of water (e.g., ocean). This method is not feasible at Camp Navajo due to the lack of a sufficient body of water to condense the steam.

Open loop or evaporative cooling can consume between 450 and 520 gallons of water per MWh, with an estimated consumption of 191 to 220 GPM for the recommended 20 MW net power plant. This consumption would far exceed the current capability of plant infrastructure and is not considered feasible due to the limited availability of water onsite.

The closed loop (air cooled) condenser has a substantially lower water consumption with a median of 4 gallons per MWh (1.5 GPM for a 20 MW net power plant). This water consumption is generated by the vacuum pumps or ejector equipment to remove non-condensable gasses, which infiltrate the power cycle loop and reduce efficiency.

It is possible to implement a hybrid of open and closed loop cooling to reduce water consumption, like the San Juan Generating Station in Farmington, New Mexico.[92] At this facility, the cooling cells are set in series, with the dry cooling first and the wet cooling second. The ratio of steam condensed in the dry and wet cooling cells will determine the water consumption of the loop, which would fall between 1.5 GPM and 200 GPM, respectively.

Boiler blowdown is the major source of water discharge in a power plant cycle common to stokers, fluidized beds, and gasifiers. Boiler blowdown typically ranges between 1 to 2% of steam flow from the boiler; for a 20 MW net power plant, the 2% rate amounts to 9.5 GPM of discharge. The deaerator is the other source of water consumption due to the need to vent the equipment to discharge any inward leakage of air and oxygen.

The three types of stokers have designs that can employ either water or air cooling of the grate bars. Water cooled grate units are required when burning low moisture and/or high energy content fuels, such as coal and kiln dried wood/wood products below approximately 20% moisture content. The fuel available to Camp Navajo ranges in average moisture well above this threshold; therefore, water cooled stokers are not necessary.

The water consumption and discharge rates for the 20 MW net power plant using a closed loop (dry) cooling, air-cooled type stoker and a standard deaerator are 20.5 GPM consumption and 9.5 GPM discharge. In different units of measure, this amounts to 30,000 GPD of consumption and 13,700 GPD of discharge.

Ability to Address Camp Navajo Current and Future Energy Needs

Camp Navajo currently uses a small amount of natural gas for space heating and hot water. Future expansion of the camp's energy demands are centered around how many and what type of businesses are deployed at the 200 Area industrial campus. As many businesses would be involved in manufacturing, steam is a common medium for delivering energy. If the future tenants could use the steam, a combined heat and power generation facility would be able to export steam in a district heating distribution system.

The incentive for a combined heat and power plant (CHP) are primarily economic. The break-even point for the steam sales on an energy basis is established by the \$4.50/MMBtu[93]

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[92] Stallings, J. Energy Power Research Institute. (2012) *Economic Evaluation of Alternative Cooling Technologies.* P. 3-23.
[93] MMBtu = million British thermal units.

($4.50/dekatherm) currently available due to the proximity of a natural gas distribution pipeline on Camp Navajo's northern border. This converts to a wood fuel cost of $58/BDT. Given the availability and cost of wood fuel in the area identified in the Feedstock Supply Assessment discussion,[94] a CHP option has the potential to generate net revenue for the plant if steam energy customers are signed to long-term offtake agreements. These agreements would have to be secured before final design of the power plant were completed so the heat release capacity of the boiler and furnace could be sized appropriately. The alternative is to design the facility for an estimated amount of excess capacity to deliver steam to onsite customers. This alternative carries risk that no long-term offtake agreements using steam will be signed and the added cost for CHP capacity will not realize an economic payback.

The disadvantage of a CHP installation is any steam sent to industrial clients has only had a fraction of the available energy used to make electricity. Fully condensed steam in a power plant makes approximately three times as much electricity as any steam extracted for industrial customers. This will significantly increase the size and cost of the power plant depending on how much steam extraction capacity is required.

Heat and Power Baseline Costs

The baseline costs of a power plant must consider both capital cost and operating costs over the life of the facility. In many instances, discounts to capital cost are married to an increase in operating costs, which are not considered in the decision making process by bioenergy facility owners. The best example of this is fixed grate stokers, which are the lowest capital cost of all biomass combustion technologies. They also have the highest labor requirements due to the need to use operators to de-ash the grates, instead of mechanical ash removal.

When comparing the installed cost of stokers and fluidized bed combustors, the results show a high degree of overlap of the cost ranges for either technology, with stokers having slightly lower overall cost of electricity generation. The fluidized bed capital cost is an average of 5% to 25% more expensive than stoker furnaces. The increased efficiency fluidized bed boilers realize about a 4% reduction in fuel consumed per year due to combustion efficiencies. When comparing the estimated capital and operating costs of fluid beds and stokers (at 20 MW of generation capacity), the stoker averages $6,000,000 lower capital cost, while requiring $225,000 more per year in fuel cost (due to lower combustion efficiency). This evaluation shows the stoker as having the lowest delivered electricity cost over all others, but only marginally better than fluid bed technology. Figure 24 provides a comparison of installed capital cost across a variety of combustor technologies.[95]

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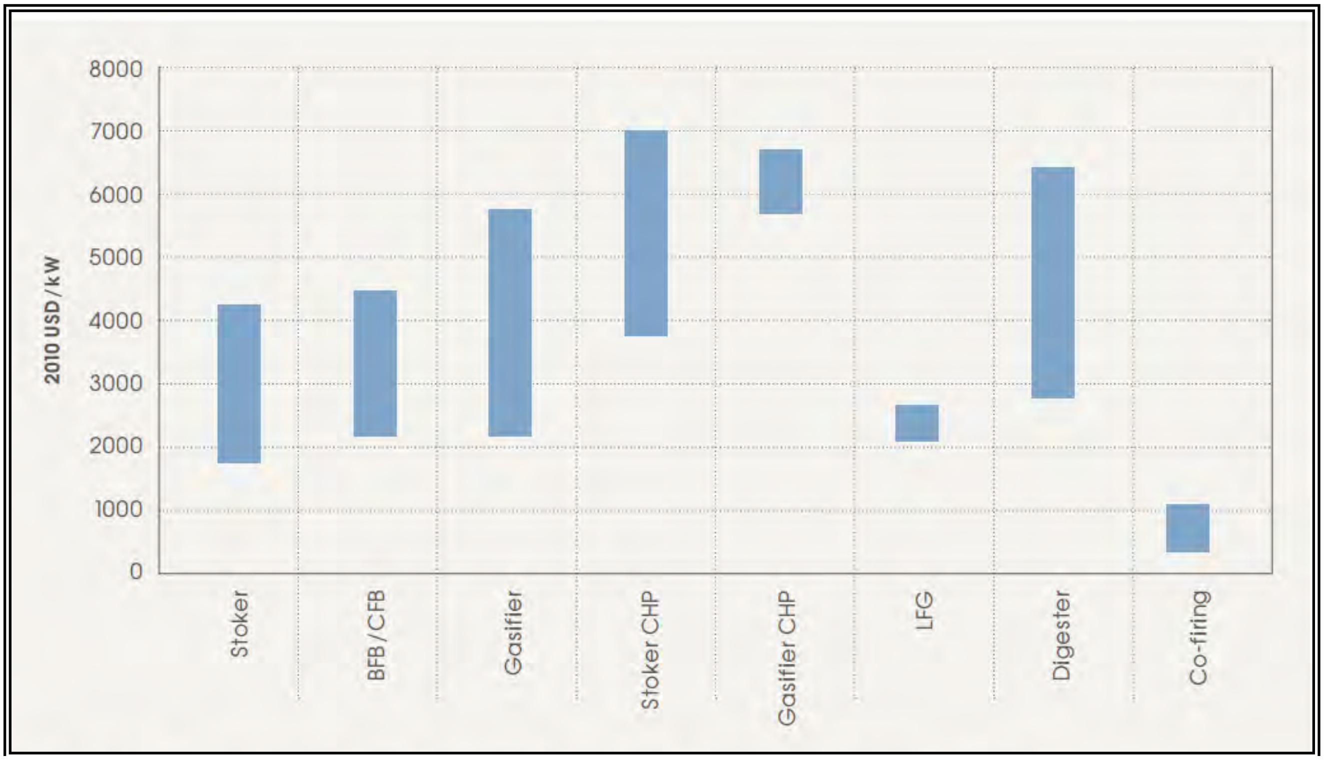
[94] Delivered fuel cost is forecast at between $41.86/BDT and $44.43/BDT for the initial five years of commercial operations.
[95] International Renewable Energy Agency (2012) *Cost Analysis of Biomass Power Generation*. Renewable Energy Technologies: Cost Analysis Series Volume 1. Figure 5.3. United Arab Emirates.

Figure 24. Installed Capital Cost Ranges by Biomass Power Generation Technology



Source: International Renewable Energy Agency

Wood fuel that is economically available from the Camp Navajo FSA does not exceed the operating limits of a stoker in either moisture or ash content. A fluid bed would be recommended if a wide variety of fuel feedstocks with varied moisture content, high heat value (Btu/dry pound) and ash content, made up a large portion of feedstock supply, but this is not the case. An example of a CFB facility designed to utilize a wide range of feedstocks is the Mt. Poso Cogeneration facility at Bakersfield, California. This plant is a converted coal burning 44 MW CFB boiler which now utilizes a wide range of biomass feedstocks including agricultural waste (e.g., nut shell, pits, orchard removals) and urban wood waste. The fuel supply for this plant has a very high degree of variability regarding moisture, energy content and bulk material handling properties. This is not the case at Camp Navajo because the fuel availability for the proposed bioenergy plant meets the consistency requirements for a stoker's normal operation.

Labor Requirements

The labor force employed by a biomass power plant is comprised of boiler operators, fuel tenders, maintenance staff and administration/management. The requirements for administration/management, boiler operation and fuel tenders are effectively the same for both stokers and fluidized bed boilers; the primary difference is the number of maintenance personnel required to perform the preventative, planned and emergency maintenance required within the facility. Stokers typically require slightly more labor to manage the relatively higher rates of ash produced (when compared to fluid bed boilers).

Selection of Preferred Technology

When combining all factors of consideration, the available technologies rank in the following order:

1. Reciprocating/Travelling Grate Stoker
2. Bubbling Fluid Bed Combustor
3. Circulating Fluid Bed Combustor
4. Close-Coupled Gasifier
5. Gasifier to ICE

Table 18 provides a summary of capital cost, O&M cost, annual operating cost and estimated cost of power generated. The costs generated are based on industry average installed capital costs, the average fuel cost data from the Biomass Feedstock Supply Availability and Cost analysis, and a 20 MW (net) plant capacity (22 MW gross). Note that a more detailed economic analysis is presented in the next section (Economic and Financial Analysis).

Table 18. Cost of Delivered Power by Technology

COMBUSTOR TECHNOLOGY	TOTAL CAPITAL COST	TOTAL ANNUAL O&M COSTS	COST OF CAPITAL (10-YEAR PERIOD)	ESTIMATED ANNUAL OPERATING COST	ESTIMATED COST OF ELECTRICITY
	$	$/yr	$/yr*	$/yr	$/MWh
Stoker - Recip/travelling	$41,360,000	$10,756,350	$4,549,600	$15,305,950	$81.85
Fluid Bed - Bubbling	$45,353,000	$10,718,893	$4,988,830	$15,707,723	$84.00
Fluid Bed - Circulating	$47,740,000	$10,933,640	$5,251,400	$16,185,040	$86.55
Gasification	$47,080,000	$10,614,510	$5,178,800	$15,793,310	$84.46
*Assumes a 10% cost of capital					

ECONOMIC AND FINANCIAL ANALYSIS

Based on the findings from Wood to Energy Technology Evaluation, including selection of the preferred wood to energy technology (stoker boiler) and confirmation of optimized project scale (20 MW), an economic analysis was conducted, focused on identifying components of the capital and operating costs, performance characteristics, cost of delivered power and markets for both the Base Case and four sensitivity cases. The Base Case is a 20 MW biomass fueled power plant without any heat customers. The sensitivity cases explore 1) using all domestic equipment, 2) selling steam at a volume that is available at no extra cost, 3) selling steam at additional volumes available with extra cost, 4) increasing the electric capacity over the Base Case, and 5) a longer power purchase agreement (PPA).

Environmental Permitting Costs

Environmental permitting fees and costs were estimated for a 20 MW biomass power plant sited on Camp Navajo property along with the principal environmental permits and approvals to site, construct, and operate the facility. The facility is assumed to require federal NEPA review, air quality permitting including an AZ Class I air quality permit and Title V as the facility could be considered a major source, and both construction and industrial (for operations) storm water permits. A wastewater disposal permit is not considered necessary as the facility is proposed to discharge any wastewater to the Camp Navajo wastewater treatment facility. If the permits are appealed, there would be additional legal and consulting fees and delays. In addition to estimated application and annual fees, Table 19 outlines estimated costs to prepare the necessary applications, documents, and supporting information and data (such as air modeling for the air quality permits).

If the biomass facility is located adjacent to Camp Navajo in the Bellemont industrial area, federal NEPA review would not be necessary. However, a CUP would be required by Coconino County. The CUP application as well as CUP review and approval process would be needed. It is believed that this process would be similar in cost to the NEPA review process listed in Table 19. All other permits listed in Table 19 would apply to either the Camp Navajo or Bellemont sites.

Table 19. Principal Environmental Permitting Fees and Estimated Costs

PERMITS/APPROVALS	AGENCIES	APPLICATION/PROCESS	FEES	ESTIMATED PREPARATION COSTS
Project Siting				
NEPA review (if needed)	U.S. Dept. of Defense	Preparation of environmental impact document	N/A	$100,000 to $150,000
Air Quality				
Class 1 Air Quality	AZ Dept. of Environmental Quality – Air Quality Division	Preparation of AZDEQ Class I permit application	No initial application fee Annual fee: $24,340 plus emission based fee of $45.40/ton of pollutant (~ $15,000 for 20 MW facility)	$50,000 plus $25,000 for initial emissions source test
Title V	AZ Dept. of Environmental Quality – Air Quality Division	Preparation of Title V permit application	See Class I Permit above	$50,000
Storm Water				
Storm Water Construction Activity General Permit	AZ Dept. of Environmental Quality – Water Quality Division	Preparation and filing of Notice of Intent under the AZ General Construction Permit, plus preparation of Storm Water Pollution Prevention Plan (SWPPP)	Annual fee: $350	Preparation of NOI and Construction SWPP: $5,000 to $10,000
Industrial Storm Water Non-Mining Multi-Sector General Permit (Sector O – Steam Electric Generating)	AZ Dept. of Environmental Quality – Water Quality Division	Preparation and filing of Notice of Intent under the AZ Industrial Storm Water Permit, plus preparation of Storm Water Pollution Prevention Plan (SWPPP)	Annual fee: $500	Preparation of NOI and Construction SWPP: $10,000 to $15,000
		TOTALS	**~ $41,000**	**~$240,000 to $300,000**

Permitting for a wood to electrical energy facility is discussed in detail in the Energy Demand Incentives and Environmental Permitting section.

Engineering, Design, Procurement, Installation and Operation Costs

TSS conducted an analysis of engineering, design, procurement, installation and operation costs for siting a 20 MW biomass power generation facility, a 20 MW facility with additional steam production capacity, and a 40 MW biomass power generation facility. In addition, the costs to utilize 100% domestic equipment were calculated. Table 20 provides capital cost estimates with line items for key components and key tasks.

Table 20. Capital Costs for 20 MW Facility, Additional Steam Capacity and 40 MW Facility

COST CENTER	20 MW FACILITY		20 MW CHP @ 150,000 LBS/HR STEAM		40 MW FACILITY	
	$	$/kW	$	$/kW	$	$/kW
Air and water permitting	$200,000	$10	$200,000	$10	$200,000	$5
Site permitting including NEPA and CUP	$150,000	$8	$150,000	$8	$150,000	$4
Prelim engineering needed for financial closing	$200,000	$10	$200,000	$10	$200,000	$5
Review engineering	$15,000	$1	$15,000	$1	$15,000	$0
MOU legal	$15,000	$1	$15,000	$1	$15,000	$0
Entity formation and governance docs legal	$15,000	$1	$15,000	$1	$15,000	$0
Third party commercial agreements legal	$300,000	$15	$300,000	$15	$300,000	$8
Lender's legal cost	$100,000	$5	$100,000	$5	$100,000	$3
Lender's fuel and engineering studies	$50,000	$3	$50,000	$3	$50,000	$1
Interconnection study	$50,000	$3	$50,000	$3	$50,000	$1
PPA legal	$100,000	$5	$100,000	$5	$100,000	$3
Inter-creditor agreement legal	$100,000	$5	$100,000	$5	$100,000	$3
Loan documents legal	$200,000	$10	$200,000	$10	$200,000	$5
Development costs before financial closing	$1,495,000	$75	$1,495,000	$75	$1,495,000	$37
Cost to construct / EPC - Site + Stoker Plant	$54,000,000	$2,700	$72,592,200	$3,630	$97,200,000	$2,430
Air cooled condenser adder	$3,187,000	$159	$3,187,000	$159	$4,000,000	$100
Waste water storage tanks	$152,650	$8	$152,650	$8	$250,000	$6
Site purchase	$0	$0	$0	$0	$0	$0
Interest during construction	$2,430,000	$122	$3,266,649	$163	$4,374,000	$109
Debt cash reserve - 6 months	$1,200,000	$60	$1,200,000	$60	$2,400,000	$60
Maintenance cash reserve	$300,000	$15	$300,000	$15	$300,000	$8
Loan fee	$480,000	$24	$480,000	$24	$960,000	$24
Interconnection upgrade	$1,000,000	$50	$1,000,000	$50	$1,000,000	$25
Contingency - 5%	$3,212,233	$161	$4,183,675	$209	$5,598,950	$140
Total Capital Cost	**$67,456,883**	**$3,373**	**$87,857,174**	**$4,393**	**$117,577,950**	**$2,939**
Domestic Equipment Sensitivity						
Domestic only adder	$3,240,000	$162	$4,355,532	$218	$5,832,000	$146
Total if Domestic Only Equipment	**$70,696,883**	**$3,535**	**$92,212,706**	**$4,611**	**$123,409,950**	**$3,085**

Cost per Kilowatt of Power Generation Capacity

Engineering, design, procurement and installation costs for the steam turbine, boiler and fuel handling equipment are included in the line item on the capital cost schedule above (see cost to construct). The cost to construct is estimated at $54,000,000 or $2,700 per kilowatt of capacity ($/kW) for the 20 MW facility. If the project were restricted to all domestic suppliers, the cost to construct is estimated to increase by $3,240,000 or $162/kW (6% increase). The cost to construct estimate is $97,200,000 or $2,430/kW for the 40 MW facility. In addition to the standard equipment, siting this facility at Camp Navajo is expected to require an air-cooled condenser which is included in the Base Case at an expected cost that adds $3,187,000 over a conventional design. For every $1 million that the capital cost increases, the cost of electricity produced increases $0.65/MWh.

The project sponsor will incur nearly $1.5 million to permit the site and finalize the legal agreements for financing, power purchase agreement, fuel purchase agreements and other arrangements. These costs include $200,000 of independent engineering studies necessary to provide assurance to the lenders that the facility will perform as described by the owner's engineers. Legal fees to draft and review financing documents, fuel supply contracts, construction contracts, and the power purchase agreement could be more than $600,000. The project sponsor will be required to pay the lender's legal fees to review the same documents. During construction, the project sponsor would incur interest estimated at $1.9 million, which is based on the balance of the construction loan during construction. The project would typically need to fund a maintenance reserve account with cash equal to the average of six months of maintenance expenses. A cash debt reserve account that covers two quarters of debt service would need to be funded as well. In addition, this analysis includes a 5% contingency. The total funding of initial capital cost needed to develop and construct the 20 MW facility is estimated at $67,456,883 or $3,373/kW for the Base Case. There are economies of scale with a higher power capacity plant. The estimated capital cost of a 40 MW facility is $2,939/kW. There does not appear to be positive economies of scale for larger steam production over the Base Case amount of 20,000 PPH as explained in the sensitivity cases.

Cost of Delivered Electricity

The cost per megawatt hour of delivered electricity from the Base Case facility is estimated at $116.65/MWh, (or 11.7¢/kWh). This rate is very similar to the annual average rate (including demand charges) for current power purchases for Camp Navajo, which is $103/MWh (or 10.3¢/kWh). The maximum demand (instantaneous usage) for the Camp peaked at 1,947 kW, which is less than 10% of the 20 MW net generating capacity of the power plant.

Four sensitivity cases were developed to explore reducing the delivered cost of electricity that include 1) selling waste heat, 2) selling additional heat produced at additional cost, 3) increasing the capacity of the plant to benefit from additional economies of scale, and 4) increasing the term of the sales contract and debt amortization. The sensitivity cases and the resulting savings are explained below.

Cost per Btu of Heat

There are various ways to analyze the cost per Btu of heat. The methodology that is most appropriate for this project is to start with the heat volume, which is freely available at a standard design that causes no additional capital cost and no additional operating cost to produce. The Base Case facility has 20 MW of electrical capacity and 20,000 pounds per hour (PPH) of steam or approximately 20 MMBtu/hr of heat capacity whether there is a customer for the heat or not. All other things being equal, one pound of steam is equal to 970 Btu (an easy rule of thumb is one pound of steam is equal to 1,000 Btu). Typically, heat buyers, such as lumber dry kiln operators, evaluate offers in $/1,000 pounds of steam. The Base Case facility produces 20,000 PPH of steam, 7,730 hour/year which results in a potential revenue stream of $695,700/year as shown in the second row of Table 21. After 20,000 PPH of steam is sold, additional steam sales will decrease power production, which is also analyzed in Table 21.

Table 21. Steam Sales Sensitivity Analysis

IMPACT OF STEAM SALES					
POWER	**STEAM SALE**	**POWER REVENUE**	**STEAM REVENUE**	**COMBINED REVENUE**	**DIFFERENCE FROM 20,000 PPH CASE**
MW/hr	**lbs/hr**	**$/yr**	**$/yr**	**$/yr**	
20	0	16,733,530	$0	$16,733,530	
20	20,000	16,733,530	$695,700	$17,429,230	
19.2	39,000	16,064,188	$1,356,615	$17,420,803	-$8,426
18.2	54,600	15,227,512	$1,899,261	$17,126,773	-$302,457
16.6	80,000	13,888,830	$2,782,800	$16,671,630	-$757,600
Assumptions:					
Power price	$108.24				
Steam price	$4.50				
Hours per year	7,730				

This analysis assumes a steam sales price of $4.50/1,000 pounds of steam or $4.50/MMBtu which is on par with the cost of heat produced by natural gas boilers. Such a sale would reduce the required revenue stream from electricity by the steam revenue amount or about $8/MWh in electric terms or 7.1% resulting in power price of $108.24/MWh (as noted in Table 21). This volume of steam is essentially free, as it is available at no additional cost in the Base Case design. This volume of steam is available whether the facility has a customer or not.

If more than 20,000 PPH of steam is extracted from the process, it will reduce power production. There is an opportunity cost of selling steam which is measured by the reduced volume of power. Table 22 provides analysis of the opportunity cost of selling more than 20,000 PPH of steam at $6.13/thousand pounds. This assumes a power price that is equal to the required cost of power in Sensitivity Case 2 (20 MW facility with 20,000 PPH steam sales)[96] at $108.24/MWh. If the power price is less due to less operating cost or the selection of one of the other sensitivity cases or other reasons, then the trade off to sell steam would change. As the power is priced less, the opportunity cost of selling steam at the expense of power production lessens.

[96] See Economic and Financial Analysis Findings for explanation of all five Sensitivity Cases.

Table 22. Opportunity Cost Analysis of Steam Sales

CALCULATION OF OPPORTUNITY COST OF STEAM SALES					
POWER	STEAM SALE	POWER REVENUE	STEAM REVENUE	COMBINED REVENUE	DIFFERENCE FROM 20,000 PPH CASE
MW/hr	lbs/hr	$/yr	$/yr	$/yr	
20	0	16,733,530	$0	$16,733,530	
20	20,000	16,733,530	$948,233	$17,681,763	
16.6	80,000	13,888,830	$3,792,933	$17,681,763	$0
Assumptions:					
Power price	$108.24				
Steam price	$6.13				
Hours per year	7,730				

Remote Steam Sales

To deliver steam or heat long distances, significant increased costs are incurred, which increase the required price for steam sales to cover expenses. Additionally, both a steam pipe and a condensate return pipe are recommended due to the cost of treating raw water to the standards of the turbine steam cycle. The cost of piping at a certain distance from the plant causes the steam sale cost to exceed the cost of steam from operating a natural gas boiler, therefore eliminating any economic advantage the potential energy customer would gain by using this steam. The estimated cost to run steam piping from the 200 Area to the Bellemont industrial area (which is ~3,000 ft of piping away) is approximately $1,136,000 (or $378/ft total installed cost). The impact of this adds about $0.60/1000 pound steam to the purchase cost, if the investment is financed with the plant on the same 15-year debt service period.

Personnel Costs

Twenty full-time equivalent (FTE) employees are required to operate either a 20 MW plant or a 40 MW plant. The employee salaries range from about $32,000 per year to $159,000 per year. The number of employees is mostly a function of covering the 8,760 hours in a year that the plant is either operating or undergoing maintenance and the amount of fuel handling by staff that is required. The fuel and ash handling systems can be designed between a completely automated system or a primarily rolling stock type system; these two equipment arrangements are accompanied with higher capital cost or higher operating cost, respectively. This analysis assumes a highly automated fuel and ash handling system to minimize operating cost, which can add up to an additional 8 full-time positions for a facility of this size. There is a significant economy of scale in labor in operating a larger plant. The 20 FTEs are listed below in Table 23.

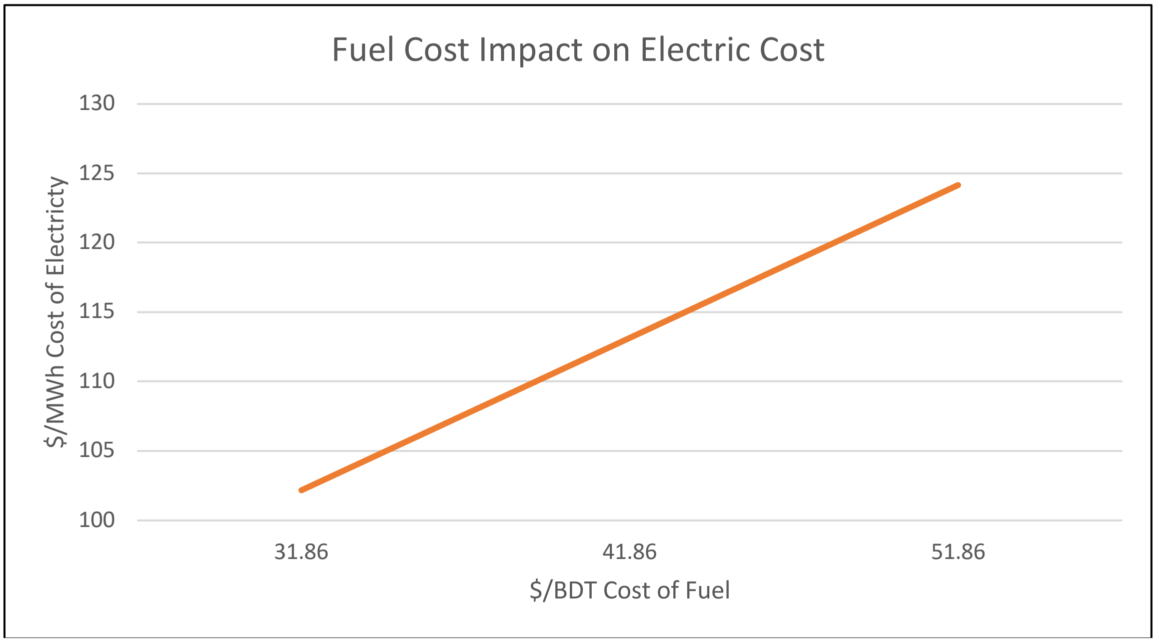
Table 23. Full Time Employee Positions

TITLE	ANNUAL WAGES
Plant Manager	$159,135
Fuel Manager	$137,917
Electrician	$75,027
HR/ Payroll Administrator	$53,045
Maintenance Manager	$79,440
Administrative Assistant	$31,827
I & C Tech 2	$53,045
Maintenance Tech 2	$47,741
Shift Supervisor 1	$58,350
Shift Supervisor 2	$58,350
Shift Supervisor 3	$58,350
Shift Supervisor 4	$58,350
Steam Plant Operator 1	$53,045
Steam Plant Operator 2	$53,045
Steam Plant Operator 3	$53,045
Steam Plant Operator 4	$53,045
Fuel Operator 1	$47,741
Fuel Operator 2	$47,741
Fuel Operator 3	$47,741
Scale House Operator	$47,741

Wood Procurement Costs Over 20 Years

The largest component of the cost of electricity is the delivered cost of biomass fuel. The pricing and availability of fuel is addressed in the Biomass Feedstock Supply Availability and Cost section. The $41.86 per BDT delivered fuel cost estimate for 2020 is equal to $46.05/MWh or approximately 41% of the total cost of power in the Base Case ($116.65/ MWh). For every $10 per BDT increase or decrease in the cost of fuel, the cost of electricity is impacted $11/MWh as illustrated in Figure 25.

Figure 25. Fuel Cost Impact on Cost of Electricity Produced



Understanding the long-term implications of delivered feedstock cost is critical to understanding the financial viability of a bioenergy facility. Summarized in Table 24 is the 20-year feedstock delivered cost forecast.

Table 24. 2020 to 2040 Delivered Feedstock Cost Forecast

YEAR	2020	2025	2030	2035	2040
DELIVERED COST ($/BDT)	$41.86	$45.10	$48.58	$52.34	$56.38

Assumptions used to calculate the range of costs summarized in Table 24 are as follows:

- The bioenergy facility is scaled at 20 MW of power generation.
- The optimized feedstock blend as shown in Table 16 is maintained over all twenty years.
- Diesel fuel and labor costs increase year to year which cause delivered feedstock costs to increase 1.5% year over year.

One of the primary factors impacting the estimated future cost of delivered biomass feedstock is the price of diesel fuel. From TSS' previous work in woody biomass collection, processing, and transport cost analysis, a $1 per gallon rise in the cost of diesel can raise the delivered fuel price by $2.25 per BDT. This assumes a 75-mile round trip transport distance. Of course, other variables such as moisture content of the feedstock, equipment blend, and the cost to mobilize equipment to the treatment area will impact this cost estimate.

Return on Investment and Payback Period

The Base Case and sensitivity cases use industry standard financing metrics and rates which are based on interviews with lenders and investors. The optimum debt service coverage ratio (DSCR) is estimated at 1.6:1. A DSCR is the operating cash flow (revenue less expenditures) divided by the debt service. It provides a measure of safety that the debt will be serviced even if operations do not produce the financial results estimated in the projections. A large debt service coverage ratio results in less debt and more equity and a more expensive capital structure. The Base Case assumes a 15-year non-recourse debt financing at the rate of the 10-year US Treasury note plus 250 basis points.[97] The total debt financing rate used in these cases is 5.5% based on the current rate of 3.0% for the 10-year treasury plus 2.5% for the spread. The 5.5% rate and 1.6:1 DSCR result in a debt sized at approximately 70% of the capital structure. The balance of the capital (approximately 30%) is provided by equity investors. The assumption is made in the Base Case and sensitivity cases that equity investors demand a 12% internal rate of return (IRR), before taxes. In our experience, equity investors and sponsors have traditionally used a 15% target IRR until recently.

Investing and lending to solar and wind projects has become mainstream financing. As a result, yields for equity investments have decreased as a greater number of investors become more comfortable and compete for investments. The *Grant Thornton Renewable Energy Discount Rate Survey Results* - 2017 reports an 8.5% average rate for equity investments in solar and wind equity. Based on interviews with investors that invest in wind, solar and potentially biomass, TSS expects investors demand higher rates for biomass projects. We considered the historical convention of the 15% rate and the wind and solar average survey rate of 8.5% and the investor interviews and estimated a new biomass project with creditworthy off takers (power purchaser or processed steam purchaser) could raise equity at 12% IRR. Other factors affecting the capital cost of the project include the capital providers' experience and opinion with the performance of the equipment and technology, the site conditions, the cash reserve accounts required for maintenance and debt expenditures, the terms of the power purchase agreements, the terms of the steam offtake agreement, the creditworthiness of the customers, loan guarantees, historical experience of the sponsor, market conditions and other items.

The unlevered payback period is 10 years. The levered or equity payback period is 8 years. The IRR rates of 5.5% to debt and 12% to equity give a more accurate picture of the return to investors and lenders than payback period because cash flows vary from year to year.
In the assumed capital structure, the 12% equity rate is equivalent to \$15/MWh and 5.5% debt rate is equivalent to \$25/MWh for a total cost to repay capital with a return over 15 years of \$40/MWh or 36% of the total cost of electricity.

Economic and Financial Analysis Findings

The financial analysis consists of a Base Case and five sensitivity cases as shown below in Table 25 and Table 26. In each case, the required revenue is calculated as the amount that pays for projected expenses and provides a return that will attract debt and equity capital to fund the initial capital expenditures as shown in Table 25.

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[97] Basis point is equal to one hundredth of one percent and is used chiefly in expressing different interest rates when conducting financial analysis.

In the Base Case project we assume a 15-year power purchase contract with a creditworthy buyer. We assume no government incentives. We assume no heat sales, only electric sales. The plant is assumed to be available 88% of the time after consideration of scheduled and unscheduled maintenance outages. In the Base Case, the cost of electricity is $116.65/MWh. The required electricity sales price in the sensitivity cases range from $86.97/MWh to $118.76/MWh. The current cost of electricity at Camp Navajo ranges from $83.50/MWh to $140.50 /MWh and averages $103.20/MWh. The current rates paid by Camp Navajo may not be 100% avoidable due to demand charges levied by APS.

The estimated value of steam sales at $4.50/MMBtu was determined based on giving an economic advantage over steam generation from burning natural gas. Camp Navajo's natural gas cost for the previous three years is $7.97/MMBtu. Converted to account for natural gas boiler efficiency, this value is $9.72/MMBtu of steam. This cost advantage provided in this economic model provides as strong a cost savings incentive as possible to attract businesses and industry to buy the steam from the power plant. More aggressive pricing strategies for steam sales would increase the revenue to the plant, but only if an off taker of the steam were guaranteed at that price. Organizing an industrial campus based on biomass energy has proven a difficult task due to their rarity in the U.S., therefore a conservative pricing strategy was utilized to provide the most incentive for co-located businesses.

Table 25. Base Case and Alternate Case Financial Analysis Findings

		BASE CASE	DOMESTIC (Case 1)	BASE CASE + 20K LBS/HR STEAM SALE (Case 2)	BASE CASE + 150K LBS/HR STEAM SALE (Case 3)	40 MW, 40K LBS/HR STEAM SALE (Case 4)	40MW, 40K STEAM EXTEND PPA AND FINANCING TERM FROM 15 YRS TO 20 YRS (Case 5)
Assumptions:							
Cost to construct	$/kW	$2,700	$2,862	$2,700	$3,630	$2,430	$2,430
Total capital cost	$/kW	$3,373	$3,535	$3,373	$4,393	$2,939	$2,939
Heat sale	MMBtu/hr	$0	$20	$20	$150	$40	$40
Heat cost	$/MMBtu	$5	$5	$5	$5	$5	$5
Fuel volume	BDT/yr	$154,608	$154,608	$154,608	$231,294	$309,216	$309,216
Fuel price	$/BDT	$42	$42	$42	$42	$42	$42
Equity IRR	Before tax IRR %	12%	12%	12%	12%	12%	12%
Debt rate	%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
Debt service Coverage ratio		1.6	1.6	1.6	1.6	1.6	1.6
Delivered Cost of Electricity Components ($/MWh)							
Fuel cost	$/MWh	$46	$46	$46	$63	$46	$46
O&M	$/MWh	$22	$22	$22	$22	$13	$13
Prop tax, insurance, admin	$/MWh	$7	$7	$7	$7	$6	$6
Steam sale	$/MWh	$0	$0	($5)	($34)	($5)	($5)
Operating cost, net	$/MWh	$76	$76	$71	$59	$61	$61
Debt	$/MWh	$26	$27	$23	$31	$20	$16
Equity	$/MWh	$15	$16	$14	$19	$12	$10
Total financing costs	$/MWh	$41	$43	$37	$50	$32	$26
First Year Cost of Electricity	**$/MWh**	**$116.65**	**$118.76**	**$108.24**	**$108.38**	**$92.66**	**$86.97**

Case 1 -- 20 MW, 15 Year PPA Restricted to Domestic Equipment

Case 1 evaluates the impact of using all domestic sourced equipment, which increases the cost to construct by 6% and the cost of electricity by 1.8% to $118.76/MWh.

Case 2 -- 20 MW, 15 Year PPA + 20,000 PPH Thermal Sale

Case 2 is the same as the Base Case except that it has a sale of 20,000 PPH of steam. 20,000 PPH is the steam available for sale without decreasing the power output below 20 MW or increasing the capital cost of the Base Case. Likely steam customers would be dry kiln operators or other process industries that have significant heat loads that are currently or would otherwise be served by natural gas, oil or electric fueled boilers and heaters. The steam sale price is assumed to be $4.50/MMBtu plus 2% per year escalation. The heat customer may recognize a benefit of not being exposed to the risk of rising natural gas prices. With the thermal sale, the cost of electricity is reduced to $108.24/MWh, which is a $8.41/MWh or 7.3% reduction.

Case 3 -- 20 MW, 15 Year PPA + 150,000 PPH Thermal Sale

Case 3 looks at installing a large boiler that could provide 150,000 PPH of steam for sale. This scenario increased the cost to construct by 34%, which in turn increases the debt and equity service costs. The expected selling price of steam is estimated at $4.50/MMBtu. At $4.50/MMBtu, this case was not useful in lowering the cost of electricity; however, it would serve additional heat customer(s) if such a market exists. The required electricity price increased in this case by an immaterial $0.14/MWh compared to Case 2, coming in at $108.38/MWh.

Case 4 -- 40 MW, 15 Year PPA + 40,000 PPH Thermal Sale

Case 4 is the same as Case 2 except that the capacity of power and steam is double in size at 40 MW and 40,000 PPH. Many of the operating expenses in a biomass power plant are fixed and semi-fixed such as labor, general and administrative expenses. Even insurance is largely fixed. Experience demonstrates there are minimum premiums required by the underwriters such that a small project pays roughly the same in insurance as a larger project. We have assumed it takes the same 20 full-time equivalent employees to operate a 40 MW plant as the 20 MW plant. Expenses that vary with size of the project include property taxes and debt service. Expenses that vary with the amount of energy production include chemicals used for pollution control/water treatment, ash handling and disposal costs. With a doubling of capacity, the cost of electricity is reduced to $92.66/MWh. Economies of scale are significant.

Case 5 -- 40 MW, 20 Year PPA + Thermal Sale

Case 5 is the same as Case 4 except that the length of the power sales agreement is 20 years instead of 15 years. As a result, the length of the financing is longer and the required loan payments are smaller. A longer PPA and debt term reduces the cost of electricity to $86.97/MWh.

Table 26. Cash Flow Projection by Case

(Figures are presented in thousands of dollars for year one of operation)

	BASE CASE	DOMESTIC	BASE CASE + 20K LBS/HR STEAM SALE	BASE CASE + 150K LBS/HR STEAM SALE	40 MW, 40K LBS/HR STEAM SALE	40MW, 40K STEAM EXTEND PPA AND FINANCING TERM FROM 15 YRS TO 20 YRS
Cost to construct	$18,035	$18,362	$16,734	$16,757	$28,652	$26,893
Total capital cost	$0	$0	$696	$5,218	$1,391	$1,391
Heat sale	$7,119	$7,119	$7,119	$9,682	$14,238	$14,238
Heat cost	$10,916	$11,243	$10,311	$12,293	$15,805	$14,046
Salaries	$1,363	$1,363	$1,363	$1,363	$1,363	$1,363
Benefits and taxes	$510	$510	$510	$510	$510	$510
Ammonia	$186	$186	$186	$186	$371	$371
Other chemicals and consumables	$139	$139	$139	$139	$278	$278
Environmental costs	$119	$119	$119	$119	$119	$119
Equipment lease - loaders (2)	$60	$60	$60	$60	$60	$60
Water	$37	$37	$37	$37	$37	$37
Waste water disposal	$2	$2	$2	$2	$2	$2
Electricity	$21	$21	$21	$21	$21	$21
Ash handling disposal	$186	$186	$186	$186	$371	$371
Insurance	$300	$300	$300	$300	$350	$350
Property taxes	$504	$504	$504	$504	$1,280	$1,280
SG&A	$112	$112	$112	$112	$112	$112
Management fee	$240	$240	$240	$240	$240	$240
Ground lease	$120	$120	$120	$120	$120	$120
Routine maintenance	$300	$300	$300	$300	$300	$300
Major maintenance reserve	$400	$400	$400	$400	$400	$400
Expense and reserve deposits	$4,599	$4,599	$4,599	$4,599	$5,935	$5,935
EBITDA	**$6,317**	**$6,644**	**$5,712**	**$7,694**	**$9,870**	**$8,111**

Table 26 shows the projected cash flow for each case in thousand dollars per year for the first year of operation. Comments regarding the differences in each case are found above in the description of each sensitivity case.

Impact of Derated Performance

Capital providers consider the impact of underperformance on the projected financial results. If the plant were derated by 10% (approximately 2 MW), it would result in decreased cash flow available after debt service of $57.72/hour. In the case of a 10% derate as shown in Table 27, the debt service is not affected but the equity investors would receive less return. If such a derate happened for the 15-year term of the PPA, the equity would receive a 9.0% IRR instead of the expected 12%. A derate situation could be caused by high ambient temperatures (although this is not expected at the Base Case design), partial equipment failures, or other reasons.

Table 27. Impact of 10% Derate of Power Output

CASE	ANNUAL CASH AVAILABLE AFTER DEBT SERVICE
Base case	$2,368,864.12
10% derate case	$1,863,251.81
Difference	$505,612.31
$/day	$1,385.24
$/hour	$57.72

PERSONNEL TRAINING

The knowledge base of the required staff for a biomass power plant exceeds typical boiler operator and manager training. As with any specialized field, the experience of operators and managers with handling and combustion of biomass, and the best practices of same, is key to the successful operation of the facility. A lot of the necessary training and understanding is shared by anyone with solid fuel boiler experience (e.g., coal fired boiler), but key differences between biomass and other forms of solid fuel must be understood. These key differences are the variability of biomass combustion and handling properties, including moisture content, ash content, particle size, heat content, and contaminants, and specifically how these properties affect combustion of the fuel and long-term, high availability operation of the boiler (baseload 24/7).

Boiler operators are a highly regulated position, in nearly all states, because of the control the individual has over equipment with enormous energy potential (high pressure boiler). If that energy were not directed or handled properly, severe damage to life and property is possible; the certification and training of boiler operators is to assure anyone at the controls of one of these plants knows how to keep the boiler and other equipment in a safe condition throughout the operational lifetime of the plant. Because of this, training is necessary for a person to be qualified to operate or maintain boilers, turbines and the associated machinery. Training duration requirements differ greatly from state to state, some requiring an equivalent amount of study and understanding as a bachelors degree, along with active experience totaling thousands of hours of commercial operation time. Arizona requirements for boiler operators are outlined in a straightforward, simple manner, but do not require any specific certifications to validate this knowledge. This knowledge includes, per the current Arizona Boiler Rules:[98]

- Knowledge of and an ability to explain the function and operation of all safety controls of the boiler;
- Ability to start the boiler in a safe manner;
- Knowledge of all safe methods of feeding water to the boiler;
- Knowledge of and the ability to blow down the boiler in a safe manner;
- Knowledge of safety procedures to follow if water exceeds or drops below permissible safety levels; and
- Knowledge of and the ability to safely shut down the boiler.

The requirements to train an operator from zero experience typically requires training equivalent to a two-year technical college course or associate degree totaling 6,000 to 8,000 hours of on-the-job training and 600-792 hours of classroom instruction. The typical cost of tuition for a full two-year program is approximately $9,000 but can vary significantly. Apprenticeship programs are also an acceptable option. One such program is sponsored by the International Union of Operating Engineers (IUOE) and typically lasts four years.

If an operator is familiar with operating natural gas or liquid fuel boilers, then a limited five day to two week seminar would be appropriate to teach them the general rules for operating a biomass/solid fuel boiler. These seminars cost approximately $550/day. An operator with natural gas/liquid fuel experience would need to be supervised by an experienced operator for three to four weeks of full-time operation before they are familiar enough with the necessary procedures and methods to operate independently.

POWER AND HEAT MARKETING PLAN

Utilities have been the traditional purchasers of renewable energy. In recent years, corporate buyers, especially technology companies (including Facebook and Microsoft), have been large purchasers of renewable electricity. Biomass produced power is carbon neutral according to the US DOE and US EPA and under most state regulated renewable portfolio standards (RPS), including Arizona. A utility seeking compliance with an RPS (known as Renewable Energy Standard and Tariff in Arizona) can source biomass power to satisfy compliance. Some people view biomass energy as a less desirable form of renewable energy than wind and solar. Purchasers that are buying for voluntary reasons are more likely to buy wind and solar because those are projects that their customers relate to when they think about renewable energy. Some buyers view biomass as very helpful in reducing wildfire risks. Although other buyers may view biomass power as supporting the forest products industry, using combustion and they don’t like seeing a related stack with air emissions and a steam plume.

Buyers of heat could be lumber dry kilns or other industrial processes that use heat and space heating, and cooling loads are good targets for this location. Heat from the biomass plant can be

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[98] Arizona Division of Occupational Safety and Health. Arizona Boiler Rules, applying to boilers, water heaters and pressure vessels. AAC Title 20, Ch.5, R20-5-417.D. 2009 Rev 2.

used to cool buildings using an absorption chiller. A power and heat marketing program would include the following activities:

1. Attend and participate in utility integrated resource planning groups for APS and SRP and in other western states in an effort to be well informed of what the utilities are seeking.
2. Propose within local utility (APS) and other utility's area request for offers (RFO) including reviewing past RFOs to determine requirements. Some conditions require long lead time such as interconnection agreements. The last Pacific Gas and Electric (PG&E) RFO in 2017 required buyers to have an interconnection study completed before being qualified to bid. The interconnection process takes about 1.5 years, begins with a significant cash deposit and can include recommendations for costly system upgrades. Costs may vary by location. There are only certain times of the year when the utility accepts applications in some jurisdictions.
3. Approach corporate buyers of renewable energy. Recently Facebook and Microsoft have been very active buyers of renewable energy and have stated aggressive goals about future purchases. Facebook, Microsoft and similar enterprises will likely have a thermal load for cooling if they were to locate a data center at Camp Navajo.
4. Pursue sales of Renewable Energy Certificates (REC). RECs are not constrained to a physical sale. A REC is a right to report the purchase of renewable energy. In this scenario the biomass facility would sell its electricity in the wholesale market without a renewable attribute attached to it, and it would separately sell the renewable attribute (in other words, the right to report a renewable energy purchase) to a different buyer. Utilities and corporations use RECs to satisfy requirements and goals for renewable energy purchases when a physical sale is more expensive or not available.
5. Become informed about state regulatory requirements for utilities to buy renewable power.
6. Recruit data centers to collocate with the power plant.

Generally selling to steam customers is done on a negotiated bi-lateral process. Generally selling to utilities is done through response to RFOs in a formal process. The bid is submitted and then a notification is sent approximately 60-120 days later with a notice of whether the proposal made the shortlist. Negotiation of contract terms and (further) due diligence begins after the shortlisting. In order to submit the lowest bid possible to the utility, it would be necessary to have an opinion whether there are going to be heat customers. It would also be helpful to have long-term biomass fuel purchase contracts in place to demonstrate to utilities that there are fuel supplies available that could support a larger project. For instance, the sensitivity cases showed a 40 MW/40 PPH project could reduce the electricity price to $86.97/MWh.

IMPACT ANALYSIS

The potential impacts associated with installation of a commercial-scale bioenergy facility can be significant, as demonstrated by previous deployments of bioenergy projects in the West. There is a robust history of bioenergy project development, mostly concentrated near forested landscapes. Following passage of the 1978 Public Utilities Regulatory Policy Act (PURPA), there was an almost immediate market response with the development of hundreds of renewable energy projects, including many commercial-scale bioenergy projects. Along with the 100 plus commercial-scale bioenergy projects deployed comes an understanding of how these projects impact local communities, watersheds, airsheds, and groundwater.

Potential Environmental Impacts

A proposed 20 to 40 MW biomass power plant would consist of biomass-fired boilers utilizing forest residues, producing steam to run electrical generation equipment. Dry cooling towers will be utilized to minimize water needs as well as wastewater discharge. For air emissions, the plant will be designed with Best Available Control Technology (BACT) for emissions such as oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter (PM).

The principal potential environmental impacts of a commercial-scale bioenergy facility generating electricity from the combustion of forest-sourced woody biomass sited at Camp Navajo to be analyzed in this feasibility study are:

- Regional and Local Groundwater Aquifers
  - Water supply impacts
  - Groundwater impacts
  - Storm water impacts
- Regional and Local Airshed
  - Air quality impacts
- Reduction of Greenhouse Gases
- Traffic
- Noise
- Visual
- Other potential impacts to natural and cultural resources may occur and would be addressed prior to plant construction during the NEPA process (Camp Navajo site) or the CUP process (Bellemont site).

Regional and Local Groundwater Aquifers

Regional groundwater resources in Coconino County occur in a series of layered and perched (at shallower depths) aquifers within rock formations between 500 to 3,000 feet below the surface. The three primary underground aquifers that provide groundwater in the region are the N aquifer (Navajo Sandstone) shallow depths, the C aquifer (Coconino Sandstone), and the R-M aquifer (Redwall and Muav Limestones). Of the three, the R-M aquifer is the deepest and underlies the entire region. The N aquifer has historically been a source of domestic, municipal, industrial, and livestock water use for the Navajo Nation, Hopi Tribe and the Community of Fredonia. The C aquifer is the main source of municipal water for the larger communities and developments in southern Coconino County. The R-M aquifer, because it is so deeply buried, is only beginning to be developed for domestic and municipal supply at smaller communities such as Williams, Valle, Supai, and Tusayan. In a few areas, most notably the Fort Valley, Bellemont, Pittman

Valley, Parks communities, as well as the northern portion of Camp Navajo, groundwater is close to the surface in perched water-bearing zones.[99]

Camp Navajo obtains its water supply from both the perched aquifer and deeper R-M aquifer, i.e. several shallow wells at approximately 300 foot depth, and one deep well at approximately 2,000 foot depth. The production rates from perched aquifer wells vary seasonally from an average total production of 80 GPM up to a maximum of 200 GPM. Although the deep well alone is capable of 70 to 80 GPM, it is significantly more expensive to pump due to the depth of the well. The shallow wells water quality is fair to good with low total dissolved solids and low to moderate turbidity, which varies seasonally.

Water Supply Impacts

Although the power plant would use an air cooled system for condensing the steam from the turbine generator set, the proposed 20 MW plant will still require approximately 25 GPM of water for its overall operations. This is approximately 12 to 13% of the currently maximum available supply water from the shallow wells, and as mentioned above, the shallow wells vary seasonally, so the overall impact may increase if only water is pulled from the shallow wells and watershed. Water use on Camp Navajo varies depending on the number of training days on the installation, which can significantly increase for certain periods of time during summer months and potentially exceed the water supply system capacity from the shallow wells. The deep water well would likely need to be used in those instances, and the power plant should compensate Camp Navajo for the additional pumping charges. Alternatively, additional shallow, near surface wells could be drilled.

As there would be storage of wood chips onsite next to the power plant, fire suppression water from hydrants will be needed for the fuel storage area. There appears to be adequate storage of fire suppression water afforded by the Camp Navajo's 1,000,000-gallon fire safety tank.

It has been proposed there will be no surface discharge of water by the power plant, so as to avoid any potential contamination to the shallow perched aquifer, as well as any surface water or soils. Currently, it is intended that wastewater will be pretreated (if necessary) prior to discharge to the Camp's wastewater treatment facility. The 20 MW plant will produce approximately 16 GPM or 23,000 GPD. Camp Navajo has a permitted wastewater treatment plant that has a design capacity of 60,000 GPD. Although it is currently underutilized and could accommodate the additional 23,000 GPD of power plant discharge, it may be exceeded during periods of additional personnel on the installation for short-term training purposes. Thus, it is proposed that the power plant have some wastewater tank storage capacity, and for up to two weeks of storage, or approximately 333,000 gallons. This tankage would be sited next to the power plant.

Storm Water Impacts

The proposed 20 MW biomass power plant as a direct combustion steam cycle system, along with a wood fuel storage yard, will require preparation of both a construction phase Storm Water Pollution Prevention Plan (SWPPP) and operational SWPPP at either site.[100] These SWPPPs

[99] Coconino County Comprehensive Plan, December 2015.
[100] Steam electric power generating facilities are required by federal law to acquire storm water permits (40 CFR 122.26(b)(14)(i)-(xi)).

will allow the construction of the biomass facility to file for a Notice of Intent (NOI) under the Arizona Discharge Elimination System (AZDES) Storm Water Construction General Permit. It will also allow for the submittal of an NOI for the ADEQ Industrial Storm Water Permit (non-mining).

With the preparation of a SWPPP for both construction and operations, any threats to groundwater aquifers should be eliminated.

Regional and Local Airshed

Air quality in the local airshed can be considered good. In regard to exceeding federal or state air quality standards, Coconino County had no exceedances for ozone, carbon monoxide, PM10 (particulate matter 10 microns or less in size) or ozone in 2016 or 2017.[101] It did meet the federal exceedance threshold of 0.07 parts per million (PPM) in 2015 for ozone.[102] ADEQ air quality maps show that the project area is in attainment of federal and state air quality standards for ozone, PM10, SOx, and carbon monoxide (CO). The closest non-attainment area is Maricopa County (for ozone), located approximately 86 miles south of the proposed project site.

Visibility, as an air quality issue, is of paramount concern in the regional airshed, principally due to the scenic amenities of the region such as the Grand Canyon. There are several areas in the region designated by the US EPA as Class I visibility areas. Such an area is provided extra protection by the US EPA in regard to visibility and scenic viewshed impairment. The proposed project site is located approximately 15 miles north from the nearest federally designated Class I area (Sycamore Canyon Wilderness Area), which will require additional modeling and evaluation to determine if there is any impact.[103]

<u>Air Quality Impacts</u>

The controlled emissions from a 20 MW woody biomass plant are estimated as: NOx, 102.8 tons/year; SOx, 45.6 tons/year; PM10, 22.8 tons/year; CO, 102.8 tons/year; VOCs, 22.8 tons/year. It is estimated that the energy output for the biomass power plant would be approximately 270 MMBtus/hour with an annual operating capacity of approximately 90% (7,884 hours/year).[104] Table 19 displays the emission factors used, estimated control efficiency, and control technology (as BACT).

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[101] 2017 Arizona Department of Environmental Quality Annual Report, http://static.azdeq.gov/aqd/air_report2017.pdf
[102] Ibid.
[103] https://www.epa.gov/visibility/list-areas-protected-regional-haze-program
[104] Annual emissions calculated at 100% capacity.

Table 28. Estimated Air Emissions for a 20 MW Biomass Power Plant

AIR EMISSION	EMISSION FACTOR IN LBS/MMBtu	ESTIMATED CONTROLLED EMISSIONS @ 100% CAPACITY (TPY)*	ESTIMATED CONTROLLED EMISSION @ 90% CAPACITY (TPY)	ESTIMATED CONTROL EFFICIENCY	BEST AVAILABLE CONTROL TECHNOLOGY
NOx	0.09	102.49	92.24	60.0%	Selective Non-Catalytic Reduction w/Urea
PM10	0.02	22.78	20.50	95.0%	Multi-clone w/ESP or Baghouse
VOC	0.02	22.78	20.50	95.0%	Mutli-clone w/ESP or Baghouse
CO	0.09	102.49	92.24	0.0%	
SOx	0.04	45.55	41.00	0.0%	

**Tons per year*

Based on these emissions and energy input, an air quality permit is required by the ADEQ Air Quality Division for the proposed project. Using the estimated emissions for the plant, it does appear that the permitted facility could be classified as a Class I permit when 100% power generation capacity is attained. In order to qualify for a Class I permit, the facility would have to have the potential to emit 100 tons/year (or more) of one of the air pollutants listed above.[105] This level of pollutants would also designate a facility as a "major stationary source." However, if the proposed project was to permit itself with a limit on operating hours, such as 90% capacity or 7,884 hours of operation/year, a Class I permit would not be needed as the facility would then be a minor source and eligible to obtain a Class II permit.

Once operating, the facility (if operating as a major source) would also be required to obtain a Title V permit. This Title V permit would be issued by the ADEQ, as it is approved by the US EPA for issuing and enforcing Title V permits. If operating as a minor source (which would require limiting operating time), a Title V permit would not be required. However, being a minor source can have its struggles, as maintaining operational limits to remain a minor source can mean increased regulatory agency scrutiny and risk to stay below the imposed limits.

It should be noted that emissions from controlled combustion of forest biomass in a commercial-scale biomass power generation facility results in significantly mitigated air emissions when compared to uncontrolled combustion of a wildfire or of forest biomass that is piled and burned in the open. Research conducted in 2014 confirmed a 98 to 99% reduction in PM (2.5 microns in

[105] Class I permits are issued to any source that meets the requirements of A.A.C. Title 18, Chapter 2, Article 302(B)(1). Such sources include: Any Major Source – A "major" source as defined by the A.A.C. Title 18, Chapter 2, Article 101(64) is any source that has the potential to emit 100 tons per year of any criteria air pollutant.

size), carbon monoxide, nonmethane organic compounds and black carbon when forest biomass is diverted away from pile burning and combusted in a commercial-scale biomass power generation facility.[106]

Reduction of Greenhouse Gases

It has been calculated that the direct combustion of forest-sourced woody biomass for a 20 MW biomass power plant would generate approximately 272,000 tons of greenhouse gases (GHG) annually.[107] The transportation of this feedstock from the nearby forests, and forests located on Camp Navajo, would generate only another 950 tons annually. However, biomass used in the production of electricity provides significant GHG benefits. Because biomass power is "carbon neutral," it displaces fossil fuel generation and reduces GHG emissions. Biomass power further reduces GHG emissions by avoiding alternative means of disposal of biomass fuel (open burning), which generate significant quantities of methane (and other air pollutants as noted above).

It is well known that energy produced from fossil fuels removes carbon from permanent geological storage and adds that new carbon to the carbon already present in the atmosphere, resulting in ever increasing carbon dioxide levels. In contrast, energy generated from biomass is now recognized as carbon neutral by the US EPA (as of April 2018).[108] This is because the carbon released by biomass power generation is already a part of the carbon cycle circulating between the atmosphere and the biosphere (e.g., trees and plants). Thus, like other types of renewable energy, including wind, solar, geothermal and hydroelectric, biomass energy production displaces GHG emissions that would have been emitted had that energy been produced from fossil fuels.

Traffic

Conveyance of biomass fuel from its source to the proposed project site is accomplished through the use of heavy-duty diesel truck and chip trailer. These vehicles can transport an average of 16 BDT of wood chips each. As 160,000 BDT of woody biomass is needed annually to produce 20 MW, a total of 10,000 truck trips will be required. These trucks will likely deliver feedstock Monday through Saturday, from 6 AM to 6 PM. With 6 major holidays (no delivery), this equates to an annual average of 307 delivery days. This further calculates to an average of 33 truck trips/day to the proposed site. It is also estimated that 50% of the trucks will come from the west, 35% from the east, and 15% from the forestland on Camp Navajo.[109]

Using Annual Average Daily Traffic (AADT) counts obtained from the Arizona Department of Transportation (ADOT),[110] the AADT for I-40 Exit 185 (the freeway exit for access to Camp Navajo) is 17,365 vehicles. Of these, 3,791 are truck and trailer vehicles. As there is reported concern regarding westbound trucks exiting at Exit 185 to access a major fueling station, the

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[106] Forest Biomass Diversion in the Sierra Nevada: Energy, Economics and Emissions, Placer County Air Pollution Control District, University of California, California Agriculture publication, 2015.
[107] Calculation based on "Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning", B. Springsteen, et al. Journal of the Air & Waste Management Association, January 2011, Volume 61
[108] https://www.powermag.com/epa-declares-forest-biomass-is-carbon-neutral/
[109] Based on discussions with natural resource managers in the greater Flagstaff area.
[110] AZDOT AADT Report 2017.

following calculations were conducted to determine any additional significant impacts that might be created should a 20 MW facility be sited at Camp Navajo.

Based on a westbound AADT at Exit 185 of 7,791 total vehicles, the calculated AADT for truck and trailer vehicles is 1,705 vehicles. Fifteen of the 33 chip van trucks would utilize the westbound Exit 185. This equals a potential daily increase of less than 1%.

There is also ongoing discussions within both the JLUS planning process and the Bellemont Area Plan Update planning process regarding access to the base via the overpass at Exit 185. Although ADOT has proposed improvements to the westbound exit and widening of the overpass to three lanes, the JLUS planning process is encouraging that the overpass be expanded to five lanes.

Noise

Onsite noise-generating equipment used in the operation of the bioenergy facility include stationary sources, such as the steam turbine, boiler, fans, pumps, and a baghouse; trucks delivering biomass fuel to the fuel storage area; and a front loader managing biomass fuel in the fuel storage area. Reference noise levels for the stationary noise sources are based on sound level measurements of an 18.5 MW biomass facility[111] in northern California. A maximum noise level was measured at 79.0 decibels (dB) at a distance of 100 feet from the power plant facility.

The nearest private residence to the proposed facility is located on the north side of I-40 in the community of Bellemont, approximately 9,300 feet northeast of the proposed power plant site. Calculating noise attenuation for that distance yields a value of 39.6 dB[112] from the power plant only[113] and with no additive noise such as traffic on I-40, which is approximately 1,300 feet from the subject private residence.

Visual

The 20 MW power plant would have presence on the landscape of Camp Navajo. The power plant (boiler superstructure) itself will be approximately 80 feet tall with a 100 foot tall exhaust stack. It would be located approximately 9,300 feet from the nearest residence whose viewshed might include the power plant.

In assessing the visibility of the power plant and stack, a comparison to the base's water tower can be made. The water tower is approximately 114 feet tall and is located approximately 4,500 feet from the nearest residence whose viewshed includes the water tower. The water tower is in the same general direction from the residence, and it is noted (from photos) that only the very top of the water tower is visible. So, it is very likely that the power plant superstructure at an additional 4,800 feet distance would not be visible. The exhaust stack might be visible but it is very thin compared to the power plant (and water tower) and would have minimal impact on the viewshed as likely only the top part might be visible.

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[111] Buena Vista Biomass Power, Ione, California.
[112] This level of noise is equivalent to a quiet office.
[113] Calculated at http://hyperphysics.phy-astr.gsu.edu/hbase/Acoustic/isprob2.html

Findings

Summarized below are the potential environmental impacts from a 20 MW biomass power plant sited at the 200 Area on Camp Navajo.

- The proposed biomass power plant would consume enough water supply to put an occasional strain on the water supplied by the Camp Navajo's shallow wells. During those periods when Soldier training levels are high, the deep aquifer well could be employed, and the added costs of electricity to pump water to supply the Camp Navajo water supply would need to be addressed by the biomass power plant.
- The proposed project could discharge water it uses for operations to Camp Navajo's wastewater treatment system, which is currently not used to capacity. As there are occasions where personnel levels are high on the base, the facility should have a two-week minimum amount of tankage for the generated wastewater.
- There will be no discharge of wastewater to surface waters or land surface.
- SWPPPs for both construction and operations of the proposed facility would address any impacts to groundwater and the shallow-perched aquifer.
- The proposed project should not present a significant impact to the regional and local airsheds. The facility could apply for a minor source permit (Class II) from the ADEQ.
- Although the combustion of forest-sourced woody biomass does generate GHGs, the process is considered carbon neutral. The US EPA in April 2018 declared biomass energy to be carbon neutral.
- Heavy-duty truck traffic generated by the proposed project will amount to a less than 1% increase at Exit 185 on I-40.
- No noise impact is calculated for the proposed facility on the community of Bellemont.
- The impact to the general area viewshed from the power plant should be minimal.

Potential Economic Impacts

A biomass to energy facility has far reaching positive impacts, ranging from direct employment of skilled labor such as boiler operators, machinists, electricians and equipment operators, to indirect jobs within the timber harvest/biomass fuels processing sector including truck drivers, equipment operators, heavy equipment mechanics and the administration staff to manage these activities. According to a 1999 study[114] by the National Renewable Energy Lab (NREL), the value of biomass power plant's environmental services alone is $114/MWh. The benefit to regional economy, employment, energy diversity and energy security is not included in this valuation. The key factor driving the benefit of biomass power to the local economy, in comparison to a similar capacity natural gas or coal fired facility, is that money spent for fuel is spent locally, as opposed to fossil fuel purchases which are typically invested outside the region.

Local Economy

The impact to local economy is an estimated 4.9 full-time positions per megawatt of net generating capacity.[115] When applied to the 20 MW net capacity results in an estimated 98 direct

[114] The Value of the Benefits of U.S. Biomass Power, 1999, NREL Publication NREL/SR-570-27541.
[115] Ibid.

and indirect full-time positions, with this number growing higher for the alternative cases of a combined heat and power plant or a higher capacity 40 MW plant. The biomass plant creates value in sorting, recovering and transporting wood waste (which would have few other beneficial uses), so it is creating additional value in the economy from an existing natural resource.

The indirect jobs created in the local economy would be primarily related to the plant operators and contractors who provide biomass fuel, namely the harvesting and transportation of biomass to the plant. The equipment used to harvest this material, as well as the plant equipment, requires supporting infrastructure of vendors, contractors, and service technicians to function at the high availability demanded by a baseload power generation power plant. The financial performance evaluation of this feasibility study estimated at $19/MWh spent for operation and maintenance and $7/MWh being subject as property tax to the county. The estimated property taxes alone would total $1.2 million per year into the local government.

Regional Economy

The benefits of the power plant to the region cover a higher level of economic impact. One of the largest impacts of biomass power using forest and grasslands restoration residuals from logging, thinning or hazardous fuels treatment operations, provides indirect benefit to the annual wildfire suppression budget of federal and state governments. In other words, forest/grassland which has the excess biomass removed reduces the severity and cost of wildfires in that area (see Fire Suppression Costs discussion below).

Additionally, the presence of more full time positions, especially during the term of the power purchase agreement (15-20 years) in the local area, improves the stability of the regional economy and cascades into more service sector (and other positions) as the people who fill those new jobs purchase homes, consumer goods and services in the regional economy.

An important benefit, which is not directly reflected in the day-to-day economy, is the stabilizing effect the biomass power plant has on energy prices. While fossil fuels have a demonstrated history of variations of 200-300% over current market value as little as 10 years ago, biomass energy costs remain much more stable. With cheap natural gas as the current favored replacement of coal generating capacity, the U.S. power grid becomes ever more dependent on an energy source which can easily experience price increase due to fluctuations in the commodity price. Installation of more biomass generating capacity makes the energy market more stable.

Energy Security

An important consideration for the power plant being located on Camp Navajo presents an opportunity to gain independence from a vulnerable power grid. Due to the large fuel inventory necessary to operate the plant because of seasonal availability of wood fuel, Camp Navajo would gain months of operating capability while off-grid, if the necessary ‘island mode’ improvements were made at the electrical substation which serves the installation and the biomass power plant. Alternatives exist to using a full power plant onsite in the form of diesel internal combustion generators, but when not in use for emergency generation, those assets are not productive for Camp Navajo nor the surrounding economy.

The biomass power plant has the ability to provide heat as well to Camp Navajo, but as identified earlier in this report, the cost savings from the energy use alone would not be enough to justify the extensive district piping system or building HVAC conversions necessary to be economical. Such a decision would have to come from the mandate for the installation to achieve energy independence from the grid in emergency or outage situations to sustain full installation activities.

Potential Cost Savings Estimates to Forestry Operations

Forest health and catastrophic wildfire have been a major concern in Arizona for decades. The 2002 Rodeo-Chediski fire consumed approximately 460,000 acres over the span of 19 days impacting the communities of Show Low, Pinetop, Heber-Overgaard and Pinedale. Following the disastrous 2002 wildfire season, congress enacted the Healthy Forests Restoration Act (HFRA), which facilitated accelerated NEPA analysis[116] and increased appropriations for forest health and fuels treatment projects.

As noted in the Feedstock Supply Availability and Cost Analysis section, the USFS manages over 892,000 forested acres in the FSA (92% of total forest cover). The HFRA has allowed the USFS to increase the pace and scale of forest thinning and fuels reduction. A major challenge within northern Arizona is the relatively undeveloped local markets for wood fiber generated as a byproduct of forest treatment activities.

Forest Thinning/Fuels Reduction

The cost of forest thinning and fuels reduction within the FSA is significant, with transportation costs being the most impactful cost center (see Table 14). Currently, forest operations residuals are being transported between 130 and 187 miles (one-way) to markets in Snowflake (Novo BioPower), Phoenix (Gro-Well), and Maricopa (Scotts Miracle-Gro). A commercial-scale bioenergy facility deployed on Camp Navajo would significantly reduce transportation costs due to reduced transport distance required to deliver forest/grassland restoration operations residuals to market. Long distance transport costs are summarized in Table 29.

Table 29. Long Distance Feedstock Transportation Costs

FEEDSTOCK TRANSPORT DISTANCE	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)
130 mile (260 to 270 mile round trip distance)	$40.31	$41.56
140 mile (280 to 290 mile round trip distance)	$42.81	$44.06
150 mile (300 to 310 mile round trip distance)	$45.31	$46.56
160 mile (320 to 330 mile round trip distance)	$47.81	$49.06
170 mile (340 to 350 mile round trip distance)	$50.31	$51.56
180 mile (360 to 370 mile round trip distance)	$52.81	$54.06
187 mile (374 to 384 mile round trip distance)	$54.56	$55.81

[116] Allowing for Categorical Exclusions for mechanical fuels treatment projects under 1,000 acres in scale within the Wildland Urban interface on federal lands.

Assumptions used to calculate the range of transport costs summarized in Table 29:

- Transport costs are calculated on a round trip distance basis;
- Average transport speed is 50 miles/hour;
- Load time is 45 minutes;
- Unload time is 30 minutes;
- Haul costs are $100/hour using conventional chip truck trailer;
- Forest and PJ biomass material average 16 BDT (net weight)/load; and
- High range cost estimate is an additional 10-miles round trip distance.

Fire Suppression Costs

The costs to conduct wildland fire suppression activities is significant and has been increasing as the Intermountain West region is experiencing wildfires with more frequency. The National Interagency Fire Center reports that the cost for federal agencies to suppress fires in 1985 was about $240 million with about 2.9 million acres impacted. In 2017, suppression costs climbed to $2.9 billion with 10 million acres impacted. As federal agencies have required more funding to support suppression activities, these funds are not available to conduct fuels treatment activities.

In 2013, the Northern Arizona University (NAU), Ecological Restoration Institute (ERI) issued results of a study that analyzed the economic impact of forest restoration treatments on fire suppression costs.[117] The study reviewed the mitigation of wildfire behavior associated with forest restoration activities on the 4FRI project. The researchers found that current wildfire suppression costs based on conditions within the 4FRI landscape average $706 to $825/acre. After forest restoration treatment activities, suppression costs should be reduced to approximately $287 to $327/acre for the same sized fire.

Wildfire Avoidance

There are a number of studies that provide documentation regarding the true value of avoiding catastrophic wildfire events and post-fire events such as flooding. In 2013, the Rural Policy Institute (RPI) at Northern Arizona University assessed the costs incurred from a 15,000 acre wildfire in Coconino County.[118] A variety of fire impacts were considered including infrastructure and utility damage, fire cleanup, damage to property and diminished property values, loss of life, loss of employment, loss of species habitat and other variables totaled between $133 and $145 million. Proactively treating all forest acres to avoid wildfire at a cost of $1,000/acre would have saved between $118 and $130 million, with an avoided cost of between $8,900 and $9,300/acre (9:1 return on investment).

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[117] *Forest Restoration Treatments: Their Effect on Wildland Fire Suppression Costs*, NAU ERI, May 2013.
[118] A Full Accounting of the 2010 Schultz Fire, 2013, Arizona Rural Policy Institute, Flagstaff, Arizona.

Findings

The estimated transport cost for a 30-mile one-way haul distance from forest or PJ grassland operations into Camp Navajo ranges from $18.53 to $20.31/BDT. If the current market for wood fiber is 130-miles one-way haul distance, the net savings in transport cost is approximately $21.50/BDT. At the 187-mile one-way haul distance, the net savings in transport cost is approximately $35.75/BDT. Of course the transport distances will vary based on location of forest operations or PJ grassland operations and market destination, but this analysis clearly demonstrates a significant net cost savings due to a reduction in fuel transport cost, should a bioenergy facility be deployed on Camp Navajo.

Fuels reduction activities conducted across forest landscapes have the potential to significantly mitigate wildfire behavior and thus reduce the number of acres impacted by wildfire. Any reduction in the funds allocated to suppress wildfire are funds that can be allocated to fuels reduction activities. ERI has studied the impact of fuels treatments upon the cost of fire suppression. Findings included a net savings in the cost to suppress fire, ranging from $379 to $538/acre.

Proactive investment in fuels reduction/forest restoration/PJ grassland restoration yields significant societal and economic benefits. While the RPI sponsored study of the 2010 Schultz Fire yielded significant cost avoidance benefits using a similar methodology for the forest landscapes surrounding Flagstaff, RPI found a range of damage costs amounting to between $573 million and $1.2 billion.[119] Clearly, proactive investment in restoring forests and grasslands and reducing hazardous fuels in northern Arizona is a worthy expenditure.

ALTERNATIVE TECHNOLOGIES

Alternative technologies that could be collocated or sited exclusively at Camp Navajo are reviewed below. These technologies and technology sectors include:

- Alternative Fuels
    - Advanced biofuels
    - Renewable natural gas
    - Anaerobic digestion
- Other Alternative Technologies
    - Biochar
    - Torrefied fuels
    - Air curtain burner with energy recovery

In addition, alternative feedstocks including municipal solid waste and biosolids were reviewed as potential feedstocks for a bioenergy facility.

[119] Flagstaff Watershed Protection Project Cost Avoidance Study, 2014, Arizona Rural Policy Institute, Flagstaff, Arizona. Report was prepared for the Flagstaff Watershed Protection Project Monitoring Committee.

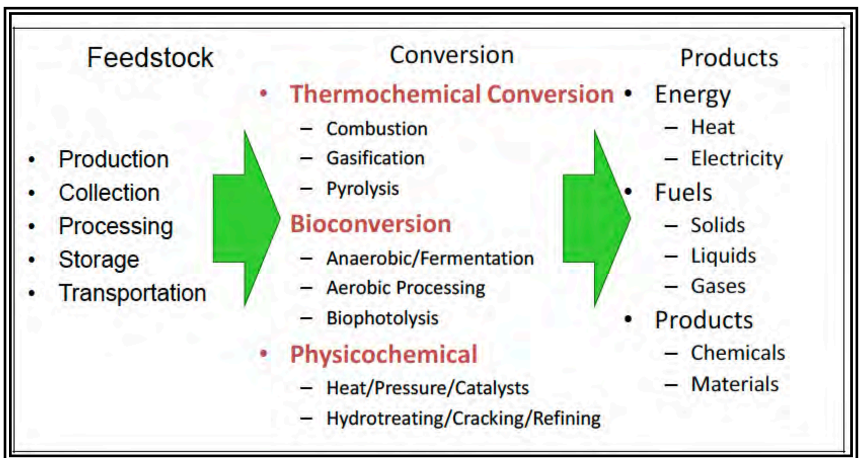
Alternative Fuels

In recent years, promising technologies have been deployed that facilitate the production of alternative fuels that can be utilized as transportation fuel or as fuel for the production of power and/or heat.

Advanced Biofuels

Biofuels can be produced through the use or conversion of biomass (referring to recently living organisms, most often referring to plants or plant-derived materials). Conversion of organic (or carbon containing) material can proceed along three main conversion pathways: thermochemical, biochemical, and physiochemical, which can produce a variety of products that include heat, electricity, solid, liquid, and gaseous fuels, chemicals and more (see Figure 26).

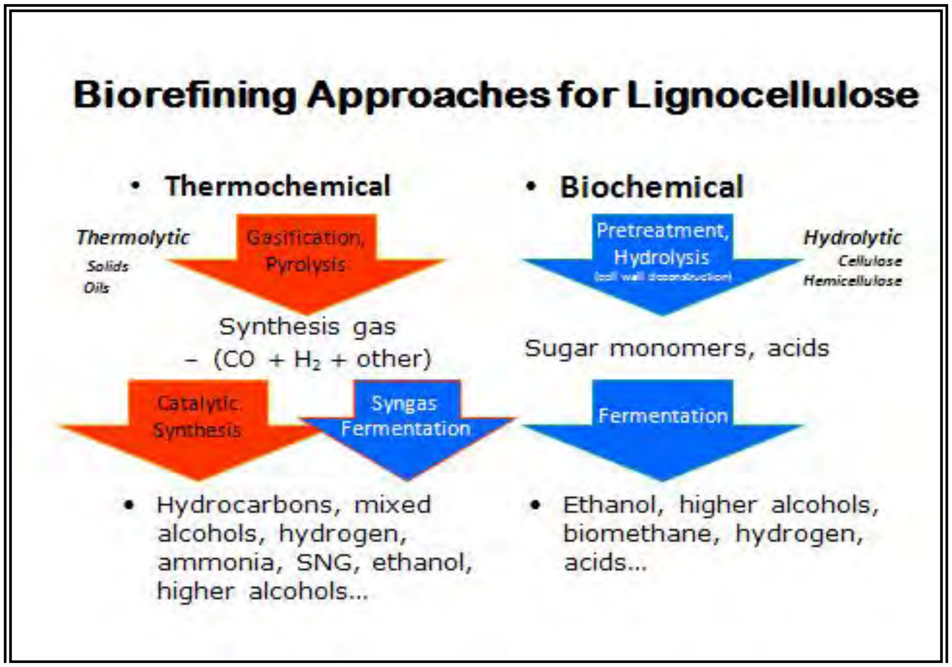
Figure 26. Biofuels Process Pathways



Source: California Biomass Collaborative

Woody biomass conversion to liquid biofuels for the transportation market would rely on the thermochemical and biochemical pathways illustrated in Figure 27.

Figure 27. Advanced Liquid Biofuels Primary Conversion Systems



Source: California Biomass Collaborative

Biochemical conversion entails breaking down biomass to create the carbohydrates available for processing into sugars, which can then be converted into biofuels and bioproducts through the use of microorganisms and catalysts. Potential fuel blend stocks include the following:

- Renewable gasoline
- Ethanol and other alcohols
- Renewable diesel
- Renewable aviation fuel

Key challenges for biochemical conversion include the considerable cost and difficulty involved in breaking down the tough, complex structures of the cell walls in cellulosic biomass. Another key challenge is to more efficiently convert the sugars into biofuels and purify them.

Thermochemical conversion of woody biomass into "drop-in" fuels[120] is generally accomplished via gasification. In gasification conversion, lignocellulosic feedstocks such as wood and forest products are broken down into syngas (primarily carbon monoxide and hydrogen) using heat. In the gasification process, feedstock is then partially oxidized or reformed with a gasifying agent (air, oxygen, or steam), which produces syngas. The makeup of syngas will vary due to the different types of feedstocks, their moisture content, the type of gasifier used, the gasification agent, and the temperature and pressure in the gasifier.

The conversion of woody biomass to liquid transportation biofuels at Camp Navajo is attractive

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[120] "Drop-in" biofuels are liquid hydrocarbons that are functionally equivalent as petroleum-derived transportation fuels.

as there are adequate biomass resources (160,000 BDT/year) to develop an economically viable commercial-scale conversion facility. The economic viability is further enhanced by the presence of rail access to Camp Navajo and to the California transportation fuel market where the California Low Carbon Fuel Standard (LCFS) program provides significant financial incentives. Liquid biofuels such as renewable diesel and aviation fuel from woody biomass could then be traded into the California LCFS program and obtain premium prices for use as transportation fuel within the state. The average California LCFS credit price as of mid-November 2018 is $183.27 per metric ton of carbon dioxide equivalent (CO_2e),[121] with indications from the marketplace that this will steadily move upward as California attempts to meet its 2020 and 2030 carbon reduction goals in the transportation sector. This LCFS credit price could provide a subsidy of approximately $2.11 per gallon. With liquid biofuels potentially sold in the marketplace at $3.17 per gallon,[122] the per gallon price realized in the California market would be over $5 (~ $5.28/gallon).

In terms of potential gross revenues, a forest biomass to liquid biofuels facility under construction in southeastern Oregon is planned to produce 15 million gallons per year using 150,000 BDT annually.[123] At $5.28/gallon, this calculates to $79.2 million per year.

Renewable Natural Gas

Renewable natural gas (also known as biomethane) is a gaseous biofuel that can be utilized in place of fossil-based natural gas in both light and heavy duty vehicles that use compressed natural gas as a fuel source. Biomethane, as the name implies, is composed almost exclusively of the methane molecule – CH_4.

There are two technological pathways used to produce biomethane from biomass; gasification and anaerobic digestion. The use of biogas from anaerobic digestion and syngas from thermochemical gasification is versatile. Biogas and syngas production can support generation of electricity and heat, or injection in the grid, or use as transportation fuel after upgrading (via methanation) to biomethane. Production of biogas by anaerobic digestion of organic feedstock in digesters or landfills is commercially well established while production of biomethane via gasification is less mature. Feedstock for biochemical production of biogas includes organic wastes (municipal, industrial, and agricultural wastes), sewage sludge, wastewater, human and animal manure, and crops (energy crops, crop residues, fresh or silage), which are not intended for use for the Camp Navajo biomass energy conversion project (with the potential exception of wastewater, see Anaerobic Digestion discussion below). Woody biomass is not suitable to anaerobic digestion because of its high content of lignin, but it can be converted into biomethane by thermochemical gasification.

The conversion of woody biomass to biomethane at Camp Navajo is attractive, as there are adequate biomass resources (160,000 BDT/year) to develop an economically viable commercial-scale conversion facility. The economic viability is further enhanced by the presence of the large

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[121] "Carbon dioxide equivalent" or "CO_2e" is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2, which would have the equivalent global warming impact.

[122] U.S. Energy Information Agency, November 30, 2018, Daily Prices, see: https://www.eia.gov/todayinenergy/prices.php

[123] Red Rock Biofuels, Lakeview, Oregon.

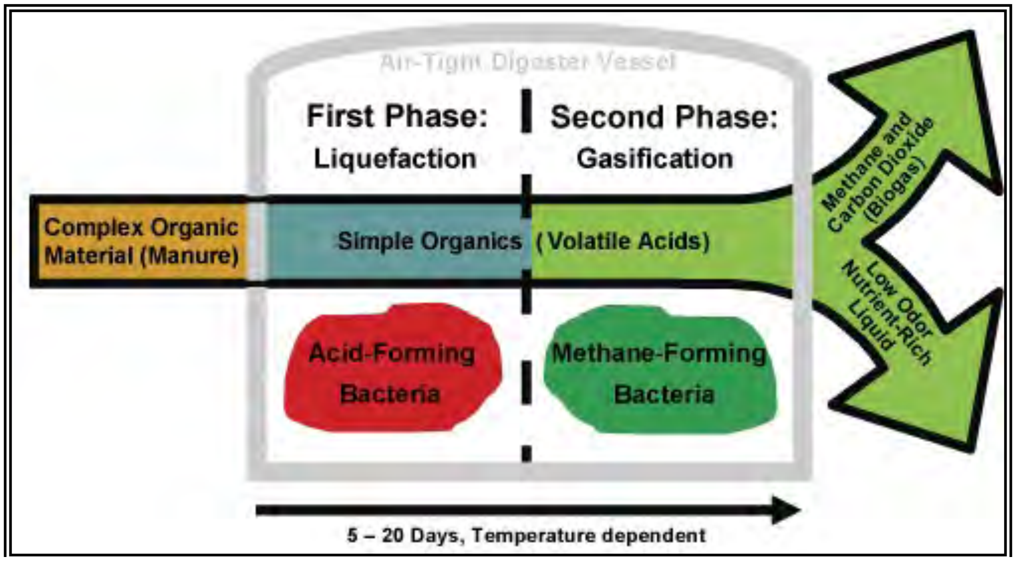
Transwestern Pipeline Company interstate natural gas pipeline near the northern boundary of Camp Navajo. This 30-inch plus gas pipeline delivers natural gas into the California natural gas pipeline system which would allow for injected biomethane from a woody biomass conversion system located on Camp Navajo. This biomethane from woody biomass could then be traded into the California LCFS program and obtain premium prices for biomethane use as transportation fuel (for vehicles, particularly heavy duty trucks that can operate on compressed natural gas). The average California LCFS credit price as of mid-November 2018 is $183.27 per metric ton of carbon dioxide equivalent (CO_2e), with indications from the marketplace that this will steadily move upward as California attempts to meet its 2020 and 2030 carbon reduction goals in the transportation sector. This LCFS credit price could provide a subsidy equivalent of $16.41 per MMBtu. Given a current natural gas price of approximately $2.70 per MMBtu, and a LCFS credit price of $16.41 per MMBtu, it could be possible that a woody biomass to biomethane project could realize $19.11 per MMBtu in the California market. Further calculations indicate that this would be a subsidy of approximately $1.89 per gallon equivalent of compressed renewable natural gas. Additionally, the biomethane produced from woody biomass could also qualify for the federal Renewable Fuels Standard (RFS), except that woody biomass sourced from federal managed lands that is not considered sustainable and does not meet RFS compliance standards. Currently, the RFS biomethane to transportation subsidy is approximately $1.93 per gallon equivalent. It should be noted, though, that the federal subsidy rate is very volatile.

Anaerobic Digestion

Anaerobic digestion is the use of microorganisms in oxygen-free environments to break down organic material. Anaerobic digestion is widely used for the production of methane- and carbon-rich biogas from crop residues, food scraps, and manure (human and animal). Anaerobic digestion is frequently used in the treatment of wastewater and to reduce emissions from landfills.

Anaerobic digestion involves a multi-stage process. First, bacteria are used in hydrolysis to break down carbohydrates, for example, into forms digestible by other bacteria. The second set of bacteria convert the resulting sugars and amino acids into carbon dioxide, hydrogen, ammonia and organic acids. Finally, still other bacteria convert these products into methane and carbon dioxide. See Figure 28 for a simple graphic of this process. Mixed bacterial cultures are characterized by optimal temperature ranges for growth. These mixed cultures allow digesters to be operated over a wide temperature range, for example, above 0° C and up to 60° C. When functioning well, the bacteria convert about 90% of the biomass feedstock into biogas (containing about 55% methane), which is a readily useable energy source. This biogas can be further purified and upgraded into biomethane, which can be utilized as a transportation fuel as previously discussed.

Figure 28. Enclosed Vessel Anaerobic Digestion Simplified Process Flow



Source: Clean World Partners

Solid remnants of the original biomass input are left over after the digestion process. This by-product, or digestate, has many potential uses, including fertilizer and soil amendments.

Wood cellulose contains lignin, which is recalcitrant to conversion into biogas.[124] Anaerobic digestion is not known to work well with woody biomass feedstocks without significant pretreatment to remove the lignin.[125] However, pretreatment of woody biomass via such methods as steam explosion could deconstruct the woody biomass and facilitate microbial access to the cellulose and hemicellulose found in woody biomass.

Additionally, technology companies are advancing anaerobic digestion of woody biomass, combined with thermochemical gasification of the cellulosic residuals, which are recalcitrant to anaerobic digestion. Discussions with Sustainable Renewable Energy[126] (SRE), a bioenergy technology company that offers an anaerobic digestion and gasification system (which reportedly can process wood waste, combined with high moisture organic waste, into biomethane), indicates that such a process could be viable at Camp Navajo.

As can be seen in Figure 29, biomass (such as forest-sourced wood waste and mill residues) can be combined with other organic wastes and processed through an anaerobic digestion vessel, which would produce biogas directly. This biogas could be upgraded to biomethane for injection into the nearby Transwestern Gas pipeline for delivery to the California transportation fuels market to take advantage of the California LCFS (as described above). The innovative part of the SRE technology would be that those woody biomass residuals that did not fully digest in the anaerobic digestion step could be dried and subjected to gasification, which could be used to produce electric power for use onsite.

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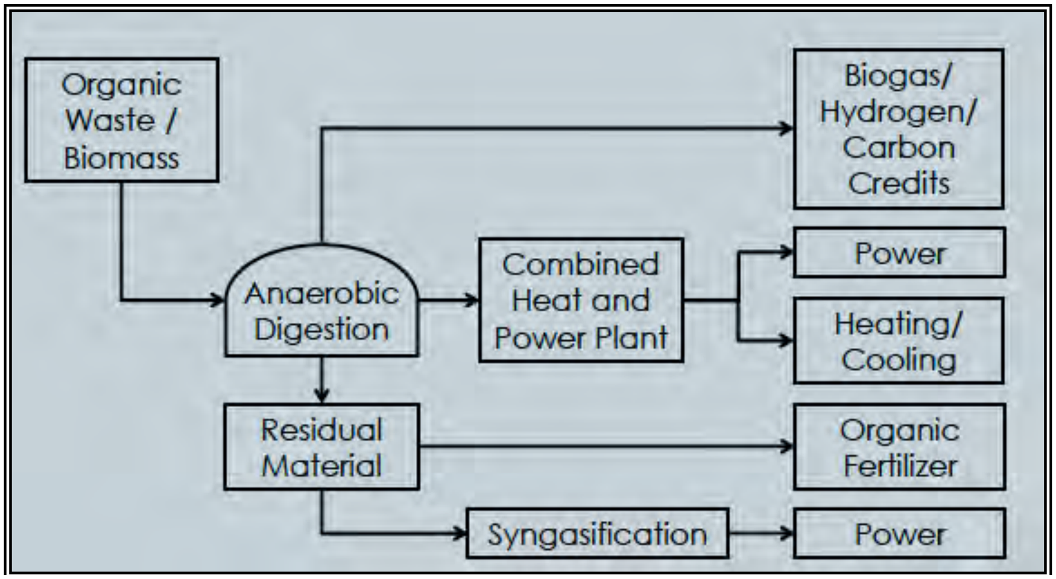
[124] Cotana, F., et.al. "Lignocellulosic biomass feeding in biogas pathway: state of the art and plant layouts", *Energy Procedia 81 (2015) 1231 – 1237*

[125] Ibid

[126] www.sre-usa.com

Figure 29. SRE Biomass Conversion Process



Source: Sustainable Renewable Energy

Although promising in that woody biomass can be utilized, no other organic wastes are expected to be imported to Camp Navajo. The anaerobic digestion portion of the process would have to rely on wastewater generated on the base as the other organic waste component for the process. Although the capacity of the base's wastewater treatment system is 60,000 GPD, the actual production from the base is between 30,000 to 45,000 GPD. It is likely that this is not enough non-woody biomass to allow the SRE system to adequately process the 160,000 BDT of woody biomass, which could be available from the regional forest management and restoration activities, forest products residuals, and urban wood waste, for delivery to the base. It is also unknown if the SRE system could be financially viable with the woody biomass feedstock component costing an average of $41.86/BDT.

Findings

Biomethane production from forest feedstocks represents a potential source of revenue if sold into the California marketplace. The principal drawback here is that large-scale woody biomass to biomethane facilities have not yet been constructed or operated in the United States and only smaller, demonstration and commercial facilities have been built and operated internationally.

Liquid biofuels present a potential source of revenue from the conversion of forest-sourced woody biomass if the produced fuels can be sold into the California marketplace and take advantage of the California LCFS program. However, cellulosic biomass conversion to liquid biofuels is still an emerging industry, even though there are several such conversion facilities under construction or planned for construction in the United States. In addition, forest biomass sourced from federally managed lands is not considered as renewable and as such is not considered compliant with the federal Renewable Fuels Standard.

Woody biomass is not suitable to anaerobic digestion because of its high content of lignin, but it can be converted into biomethane by thermochemical gasification.

Alternative Technologies

In addition to the woody biomass-derived transportation fuels discussed above, there are other potential woody biomass utilization technologies which could be deployed at Camp Navajo and in the regional forests including biochar, torrefied fuels and air curtain burner.

Biochar

Biochar is a thermally altered form of carbon that is typically a byproduct of biomass power generation (gasification process) or can be manufactured with a stand-alone pyrolysis system. Biochar is largely fixed carbon (typically 70% to 85% organic carbon) and is a charcoal or ash-like substance. It is highly resistant to decay in the environment, with a potential residence time into thousands of years, basically making a sequestered carbon product.

Biochar production occurs via pyrolysis, wherein woody biomass is heated in the absence of oxygen to temperatures generally between approximately 600 to 1,300 degrees F. This causes volatile and combustible vapors and gases to be released from the biomass without being combusted (or burned due to the absence of oxygen) and leaves the biochar product behind. The combustible vapors and gases produced during the biochar production process can be captured and used to produce process heat, electricity, and potentially liquid fuels. The biochar product can be used for multiple environmentally beneficial applications. Thus, there are three principal benefits of biochar production and utilization: 1) generation of biomass-based energy, 2) sequestration of carbon, and 3) production of environmentally beneficial products.

Biochar production from pyrolysis can yield 20 to 25% of the amount of woody biomass input. Thus, if 160,000 BDT of woody biomass is converted to biochar, the resulting yield is 32,000 to 40,000 tons.

The unique properties of biochar materials allow for use in a variety of environmentally beneficial applications including:

- Incorporation as a soil amendment to increase water and nutrient retention in poor and degraded soils;
- Removal of contaminants from supply water, wastewater, and storm water;
- Soil and mining wastes remediation;
- Reduction of air pollutant emissions (i.e., volatile organic compounds, odors, greenhouse gases, and smog forming agents) from composting when incorporated as a bulk agent; and
- Replacement of perlite and peat in horticultural potting media.

Initial biochar interest focused on agricultural applications to improve soil quality including water retention and nutrient retention properties. However, given the current price of pyrolytic biochar (upwards of $0.75 per pound) means higher value applications are more likely to be economically feasible. Biochar-based air and/or water contaminant filters in wastewater treatment plants is one of the more promising emerging applications. Considerable research is underway in this sector.[127]

The high sorption capacity of biochar owes primarily to its extreme porosity and surface area, as biochar can be more than 90% pore space and exhibit greater than 4,000 square feet of surface area per gram. These biochar surfaces are located within nanometer-sized pores that contain reactive sorption sites, where contaminants can become trapped indefinitely. Biochar is similar to activated carbon (AC) in many ways, with research conducted recently at Oregon State University showing significant sorption rates of heavy metals. One significant difference between biochar and AC is price. AC can be in excess of $3,000 per ton[128] and is generally imported from Southeast Asia. Biochar can be purchased at a much lower price and can be used for broader ranges of applications.

The biochar market as a soil amendment additive is still in development and subject to significant market price fluctuations. Biochar has sold in small quantities for over $1/pound and in bulk for $250 to $2,000/ton, indicating that the biochar market is still trying to find a stable price point. Interviews with biochar processors[129] suggested that the market for biochar is also expanding due to the recent legalization of commercial cannabis operations in California, Oregon and Washington. Other uses of biochar, particularly once its viability is established in the AC sector, suggest that there could be higher market prices for the biochar product line in the near future.

Using a conservative benchmark price of $250/ton of biochar, the 32,000 to 40,000 tons of biochar that could be produced from 160,000 BDT of woody biomass delivered to Camp Navajo from regional sources would result in gross revenues of $8 to $10 million.

Torrefied Fuels

Torrefied fuels are produced from low temperature pyrolysis of woody biomass waste so as to increase the quality of the feedstock as a solid fuel. Known as torrefaction, this process primarily utilizes woody feedstocks in the production of a solid fuel product that can be combusted in both biomass-fired and coal-fired power plants.

Torrefaction is low-temperature (approximately 400 to 600°F) pyrolysis that is used to remove water and volatile material from the wood feedstock. Through the process of torrefaction, wood feedstock is subjected to an oxygen-free environment where the elevated temperatures evaporate volatile compounds to yield a dry product that is no longer biologically active (e.g., subject to aerobic or anaerobic decomposition).

Torrefied wood can be processed into a briquette or pellet. Torrefied wood is a solid fuel substitute for coal or wood chips. Advantages of torrefied wood over standard wood chips are that torrefied wood does not decompose, is more energy dense, does not contain water (reduced

[127] For example, the California Association of Sanitation Agencies received a 2017 U.S. Forest Service Wood Innovations Grant to examine wood-based biochar as an alternative adsorption media for the control of off-gasses at wastewater treatment plants. This project is currently underway.
[128] See: https://www.alibaba.com/showroom/activated-carbon-price-per-ton.html
[129] Greg Shipley, BioEnergy Design, and Greg Stangl, Phoenix Energy.

transportation costs), will not absorb water (hydrophobic) and is more homogenous in composition. When compared to coal, torrefied wood has lower sulfur content while still having sufficient energy density to be co-fired with coal, thereby reducing sulfur emissions without substantial or costly modifications to the power plant equipment. The heating value of coal and torrefied fuel are also similar but with the ash remaining with torrefied fuel being much lower than coal. Additionally, co-firing with torrefied wood will provide benefits through GHG reduction.

Through the pyrolysis process, a low energy syngas is produced which can be used for onsite electricity generation. Typically this syngas is returned to the system to maintain the pyrolysis temperature as necessary and flared when there is excess. Economies of scale for electricity production may be a constraint depending on the size of the torrefaction operation.

Torrefied material can be transported using the same transport systems that deliver wood chip feedstock. This offers significant flexibility in siting a facility to optimize the transportation costs of delivering the feedstock and the end product.

The largest barrier to market penetration of torrefied material is the current market price of coal and natural gas. These two fossil fuels represent the low cost leaders for electricity production. Balancing the processing cost of torrefaction with the cost savings from transportation and handling is challenging. With the relatively low price of natural gas, many large-scale coal plants reaching the end of their service life are considering switching to natural gas due to the increasing emissions regulations that drive up the cost of electricity production from coal, as additional air emission mitigation technologies must be deployed. Currently, coal and natural gas are approximately $2.20/MMBtu and $3.41/MMBtu, respectively.[130] A recent study of torrefaction economics indicates that torrefied biomass was in the $6.90/MMBtu to $7.84/MMBtu range.[131]

Air Curtain Burners with Energy Recovery

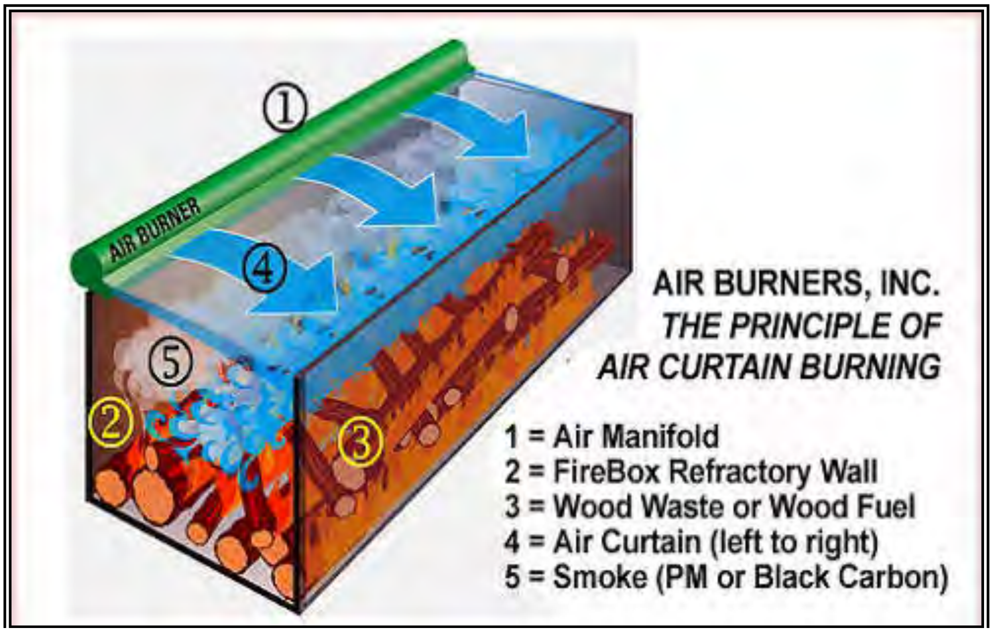
A recent technology development by the principal air curtain burner manufacturer is also being evaluated for use at Camp Navajo and in the regional forested areas, where forest and hazard fuels reduction activities are currently underway. Air Burners, Inc. (Palm City, FL) has developed the PGFirebox, which is not only a relatively low cost method of handling forest residues (no need for grinding the woody biomass prior to combustion) but can generate electric power for onsite use or the nearby electric grid (if available for interconnect).

Air curtain burners were designed principally as a pollution control device for open burning of woody material. The primary objective of an air curtain machine is to reduce the PM, or smoke, which results from burning wood waste. Using a technology called "air curtain," the smoke particles are trapped and reburned, reducing them to an acceptable limit per US EPA guidelines (see Figure 30). Also, air curtain burners negate the need to grind the woody biomass, as whole

[130] U.S. Energy Information Agency, March 2018. https://www.eia.gov/outlooks/steo/tables/pdf/2tab.pdf
[131] "Systematic Review of Torrefied Wood Economics." Radics et al. (2017), BioResources 12(3), 6868-6884 https://bioresources.cnr.ncsu.edu/wp-content/uploads/2017/06/BioRes_12_3_6868_REVIEW_Radics_GBK_Systematic_Review_Torrefied_Wood_Economics_11719.pdf

wood can be placed in the burn box, thus reducing costs and additional PM generated during grinding operations. Air curtain burner throughput ranges from 1 to 2 tons/hour in a smaller machine, to 10 plus tons/hour in a larger machine. Hundreds of these units have been deployed throughout the United States and the world. Coconino County purchased one several years ago for use in forest restoration activities.

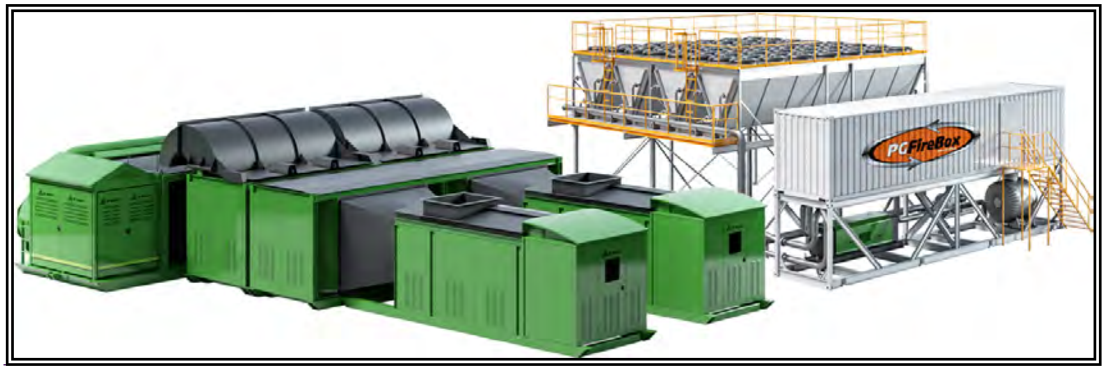
Figure 30. Air Curtain Burner



Source: Air Burner, Inc.

The PGFirebox goes the next step and adds a power generation component, which captures a portion of the heat to generate electricity (see Figure 31 for a graphic display of a 1 MW unit). This diverted heat is directed to a heat exchanger to heat thermal oil, which in turn supplies thermal energy to an Organic Rankine Cycle (ORC) power generation unit. The ORC utilizes an organic working fluid in a reverse refrigeration process where the thermal energy input to the system is converted to electrical energy by driving an asynchronous (induction) generator. The system is connected to the local electrical grid in accordance with local regulations where either some or all of the energy is consumed onsite and any excess energy produced is sold back to the utility. The ORC generation step requires cooling to recondense the organic working fluid so the cycle will continue. For arid areas such as Arizona, this cooling can be accomplished by an air-cooling system.

Figure 31. One MW PGFirebox



Source: Air Burner, Inc.

Air Burners, Inc. reports a cost of approximately $3.5 million/MW installed. These units are also highly portable (all components can be transported with standard heavy duty truck and trailer, with a few days required for set-up). The PGFirebox also comes in 100 kW and 500 kW configurations. The 100 kW unit, due to lower economies of scale, is priced at $750,000. Cost to generate power is estimated to be $0.20/kWh.[132]

Findings

Biochar, particularly in combination with other biomass conversion technologies, such as the use of gasification technologies to produce biofuels, could be accomplished. Stand-alone biochar production is also a distinct possibility; although it is a nascent technology sector, there are numerous such conversion units currently in the marketplace.

The production of torrefied fuels is also becoming a technically proven conversion technology in the United States and internationally. However, as it is basically a coal substitute, the large differential between the low price of coal and the higher price of torrefied woody biomass will likely inhibit its market penetration in the United States.

Air curtain burners with energy recovery is a novel approach to create both electricity and essentially "dispose" of excess woody biomass sourced from Camp Navajo and other forest ownerships. In addition, these units can be moved around the landscape to minimize (or eliminate) transportation costs, as well as the need for grinding or chipping the biomass and their associated costs.

Solar and Wind

Solar and wind should be considered potential collocated alternative energy systems which could add to, and complement, a bioenergy development project at Camp Navajo. Below is a discussion of the solar and wind resources catalogued for the Camp Navajo area and their potential use.

Solar

[132] Information obtained from Air Burners, Inc., Palm City, FL

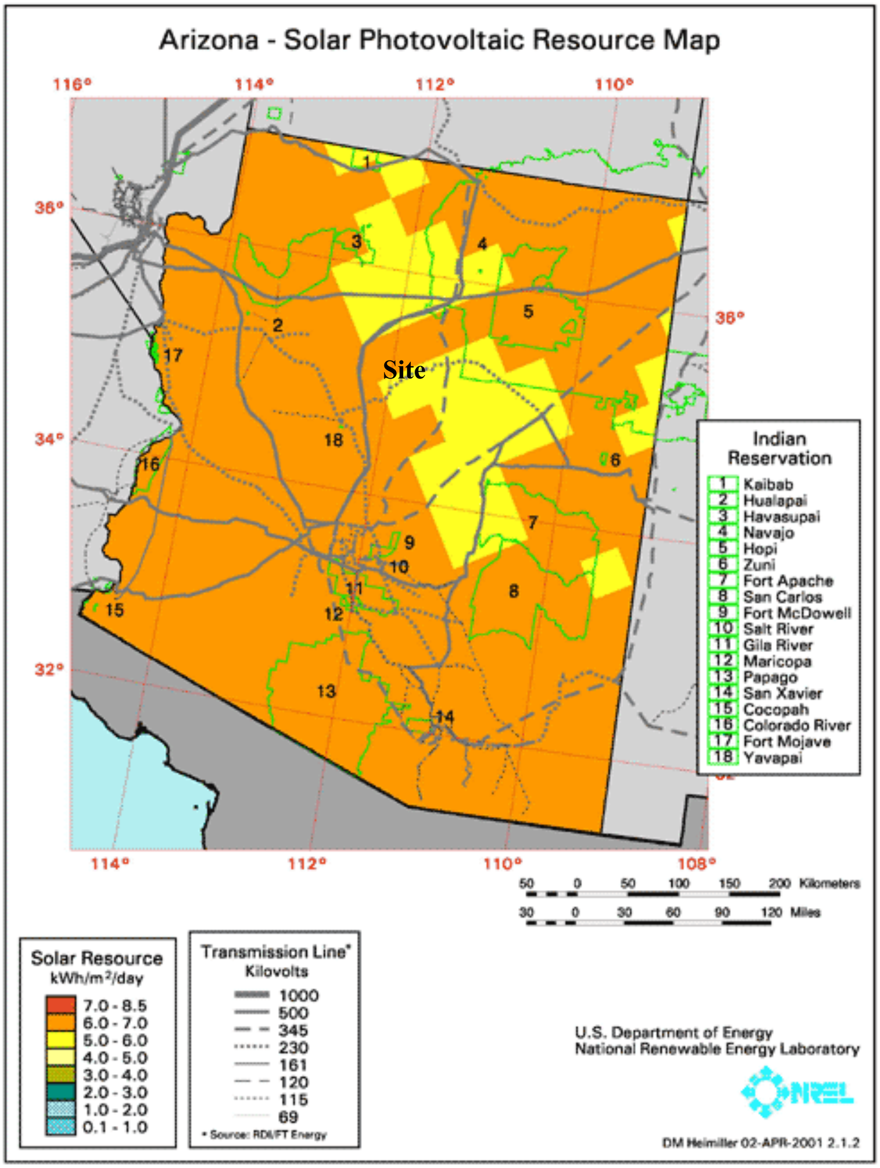
Arizona is a prime region for the generation of electricity via solar technology such as photovoltaic panels. It has the highest solar insolation in the United States.[133] Arizona has, as of September 2018, 629 MW of solar photovoltaics on line, with 430 MW at the utility scale and 198 MW at small scale (much of it being rooftop arrays). Arizona also has 90 MW of utility scale solar thermal online as of September 2018.[134]

Solar is, however, an intermittent resource for the generation of electricity, as photovoltaic panels only operate during daylight hours and operate fully only during peak sun hours, which for the Flagstaff area is an average of six hours per day.[135] There are the "shoulder" hours where the panels can still generate electricity but not at full capacity. The intermittency of solar generation can be enhanced or supplemented by the baseload electricity generation of biomass, which can operate 24/7 for about 90% of the year.

Utilizing a solar insolation map prepared by the National Renewable Energy Laboratory in Figure 32 below, it appears that the Camp Navajo property is in a good solar insolation position (5.0 to 7.0 kWh/m2/day). The kilowatts/hour/square meter portion of solar insolation is the solar irradiance value which is the instantaneous measurement of solar power over a given area.

[133] Solar insolation is the amount of electromagnetic energy (solar radiation) incident on the surface of the earth. This refers to the amount of sunlight shining down on the area under consideration.
[134] U.S. Energy Information Administration, November 27, 2018, https://www.eia.gov/state/search/#?1=104&2=184
[135] See: https://www.turbinegenerator.org/solar/arizona/

Figure 32. Solar Insolation Values at Camp Navajo



Using the midpoint insolation value for the Camp Navajo site of 6.0 kWhr/m2/day, Table 30 is presented. The solar installation consists of non-tilting photovoltaic panels, and a 20 MW facility is envisioned and is outlined.

Table 30. Solar Energy Production and Cost Calculation

PARAMETERS	VALUES
Solar insolation in kWh/m2/day	6.0
Calculated watts per square meter (irradiance)	250.0
Solar panel efficiency[136]	16%
Calculated watts per square meter	40
Square meters per acre	4,047.0
Potential kilowatts per acre of panels	161.9
Less 25% contingency	121.4
Acres needed per MW	8.2
Land needed for 20 MW	164.7
Peak sun hours average in Flagstaff	6.0
"Shoulder" hours	2.0
MWh generated per day	160.0
Price per MWh from utility	$80
Amount per day	$12,800
Amount per year	$4,672,000
Cost per MW to install per acre	$3,000,000
Cost of 20 MW facility	$60,000,000

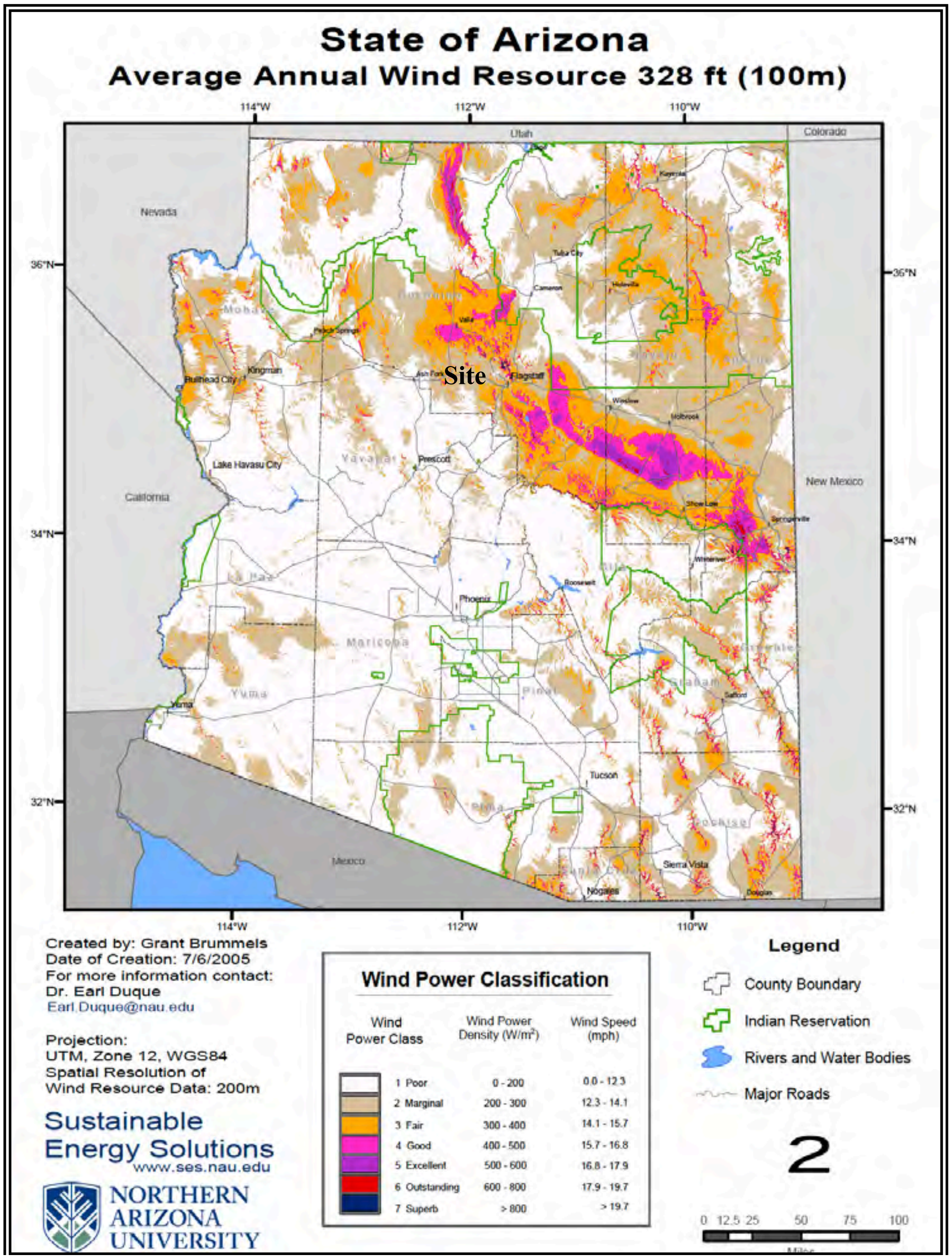
As can be seen in Table 30, a 20 MW solar facility would require about 165 acres of land. There appears to be this amount readily available on Camp Navajo. Eighty dollars a megawatt hour of electricity obtained from the purchasing utility was used in the calculations, along with an estimated cost of $3 million/MW as the facility installation costs (panels included). It is calculated that $4.67 million in annual revenues could be realized. However, the facility would have a total capital cost of about $60 million. There is also a federal solar tax credit, also known as the investment tax credit, which allows for 30% of the cost of installing solar energy systems for entities that pay federal taxes. There was also a federal solar production tax credit previously available, but it expired as of December 31, 2017.[137]

Wind

Arizona wind resources are not as robust as solar resources. Arizona currently has 268 MW of wind power in commercial service.[138] As seen in Figure 33, wind resources at Camp Navajo are considered fair to marginal, with wind speeds 100 meters (328 feet) off the ground not exceeding 15.7 mile/hour (wind speeds closer to the ground will generally be slower). Wind turbines start operating at wind speeds of 9 to 11 mph, reaching maximum power output at around 33 mph. Utility-scale wind farms aim for average wind speeds between 12 and 18 mph, which could allow for larger scale wind power on Camp Navajo. The price of an installed commercial 2 MW wind turbine to generate electricity ranges from $3 to $4 million. Using the benchmark of 20 MW to be installed, this results in a total capital cost of $30 to $40 million.

[136] Solar PV is currently about 15% efficient. See: https://sciencing.com/average-photovoltaic-system-efficiency-7092.html
[137] See: http://programs.dsireusa.org/system/program/detail/734
[138] See https://windexchange.energy.gov/states/az

Figure 33. Potential Wind Resources at Camp Navajo



With levelized cost of wind-generated electricity being $50/MWh[139] and with an annual generation capacity of 25 to 40%, the potential gross revenue would be $2.2 to $3.5 million, excluding any wind production tax credit of $18 to $23/MWh. The federal renewable electricity production tax credit (PTC) is an inflation-adjusted/kWh tax credit for electricity generated by qualified energy resources and sold by the taxpayer to an unrelated person during the taxable year. The duration of the PTC is 10 years after the date the facility is placed in service. The tax credit is phased down for wind facilities and expires for other technologies commencing

[139] Wind Technologies Market Report, Lawrence Berkeley Laboratory, 2017. https://emp.lbl.gov/wind-technologies-market-report/

construction after December 31, 2016. The phase-down for wind facilities is described as a percentage reduction in the PTC amount described above:[140]

- For wind facilities commencing construction in 2017, the PTC amount is reduced by 20%
- For wind facilities commencing construction in 2018, the PTC amount is reduced by 40%
- For wind facilities commencing construction in 2019, the PTC amount is reduced by 60%

Findings

Technically, both wind and solar (photovoltaics) energy systems can be collocated at Camp Navajo. Additional evaluation would be required to investigate if there was ample space for a 20 MW solar farm, as it would need approximately 165 acres.

As considerable space is required between 2 MW wind turbines, each turbine (due to the need to maximize wind power generation efficiency) requires about 0.2 square miles,[141] or about 128 acres. Thus a ten unit 2 MW wind farm (total of 20 MW) would need approximately 1,280 acres on Camp Navajo.

Based on a brief economic and financial examination, both 20 MW solar and wind projects with the estimated price per megawatt hour and calculated capital costs, additional detailed analysis is needed to determine if either is economically feasible. Simple payback periods appear to be lengthy based on the analysis done for this study.

Alternative Feedstocks

Bioenergy technologies have been adapted to address waste streams that could be utilized as feedstock. Waste streams that are typically landfilled are municipal solid waste and biosolids.

Municipal Solid Waste

Municipal solid waste (MSW), more commonly known as trash or garbage, is defined by the US EPA as "wastes consisting of everyday items such as product packaging, grass clippings, furniture, bottles and cans, food scraps, newspapers, appliances, consumer electronics and batteries." Some of this material can be sorted, reused and recycled which is a better alternative than disposal in a landfill. Landfill disposal for most communities is the least desirable disposal option due to a strong desire to extend the service life of landfills, reduce the potential for groundwater degradation and reduce methane emissions. Siting new landfills is becoming a huge social issue, as communities are typically not supportive of new landfills, which motivates a strong desire to extend the service life of existing ones.

In some parts of the U.S., MSW is sorted to create a solid waste fuel known as refuse derived fuel (RDF). RDF is made up of waste that is considered combustible, with non-combustibles such as metal and glass removed. Once sorted and shredded, RDF is made available to waste-to-energy facilities as a primary fuel. Economic RDF production requires economies of scale not

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[140] See: https://www.energy.gov/savings/renewable-electricity-production-tax-credit-ptc
[141] See: https://sciencing.com/much-land-needed-wind-turbines-12304634.html

available in northern Arizona. However, wood waste (e.g., tree trimmings, construction and demolition wood), sorted at area landfills and transfer stations can be readily used as fuel (see urban wood discussion in the Biomass Feedstock Supply Availability and Cost section).

In addition, MSW includes food waste (and other organics) that could be sorted directly from the source and potentially utilized as feedstock for generation of biomethane (using anaerobic digestion).

Biosolids

The term "biosolids" is defined by the US EPA as treated sewage sludge. Typically processed at waste water treatment facilities, biosolids that are treated using US EPA standards for pollutant and pathogen reduction are typically land applied or landfilled. Heat-dried biosolids are occasionally utilized as a solid fuel co-fired with fossil fuels (coal or natural gas).

Challenges with the use of biosolids as fuel include odor control and potential impacts on wood ash and air emissions (heavy metals). Like RDF processing, economic processing of biosolids requires economies of scale not found in the northern Arizona area. In addition, the preferred siting location on Camp Navajo (Area 200) is close to the community of Bellemont, which is not likely to support the use of biosolids.

Findings

MSW and biosolids are not considered commercially available feedstocks for a commercial-scale bioenergy facility at Camp Navajo. Urban wood waste sorted from the MSW waste stream in the form of processed tree trimmings, and clean construction/demolition wood is potentially available (as noted in the Biomass Supply Availability and Cost section) and should be considered as a viable, cost effective feedstock.

COLLOCATION OF ENTERPRISES

Collocation of forest products manufacturing facilities with a bioenergy facility is a common occurrence in North America. Most forest products enterprises generate significant volumes of wood waste (e.g., sawdust, bark, shavings, chips). A ready option for disposal of these wood wastes is utilization (preferably nearby) as fuel in a bioenergy facility. In addition, these enterprises have a fairly significant power demand and heat load, which a commercial-scale bioenergy facility will be able to provide on a baseload (24/7) basis.

Oriented Strand Board Production Facility

Oriented strand board (OSB) is an engineered panel that was initially developed as a substitute for plywood. In the 1970s the raw material supply for plywood production (large logs) became an issue as land managers reduced the harvest of old growth timber to address concerns regarding endangered wildlife species that relied on old forests (e.g., spotted owls). Forest products engineers adapted existing composite panel technology (particleboard production) to produce an engineered panel with robust structural properties that could serve as a substitute for plywood. In the 1980s the process to produce OSB at a commercial-scale was perfected. A major advantage of the OSB process was its ability to utilize small diameter logs as the primary raw material.

Over the years, OSB production has ramped up and there are now 53 commercial-scale facilities in North America. Seven of these facilities are currently idle, likely as a result of the 2008 to 2012 drop in North American housing starts. Scale of annual production at these facilities ranges from 270 to 1,300 million square feet (MMSF). Average annual production capacity for a North American facility is 560 MMSF. Facility locations are concentrated in Canada (across all of the provinces) and in the U.S. southeast. Currently there are no OSB production facilities operating in the western U.S.

A 2018 study conducted in northern California analyzed the potential to site a commercial-scale OSB production facility near Anderson, California.[142] In order to achieve economies of scale and produce price competitive panels, the analysis scaled the facility at 750 MMSF/year capacity. Total raw material annual demand at this scale is approximately 500,000 BDT of logs. Capital expense to design, engineer and install this facility was estimated at $298 million.

Siting a commercial-scale OSB facility alongside a bioenergy facility will facilitate cost effective delivery of processed steam and power. An OSB facility scaled at 750 MMSF/year capacity is forecast to require 8.5 to 9.5 MW of power.[143] In addition, the facilities could share onsite infrastructure (e.g., weigh scales) and skilled labor. Direct access to a class one railway (BNSF) is a major consideration for an OSB production facility.

Sawmill

Collocation of a commercial-scale sawmill alongside a bioenergy facility is a common practice in North America. The advantages of this arrangement include delivery of cost effective baseload power, cost effective processed steam, and sharing of onsite infrastructure (similar to collocation of an OSB facility). A major advantage of the Camp Navajo site is access to a class one railway (BNSF) for shipment of finished product (lumber) and residuals (e.g., pulp grade chips) to pulp mills in the Pacific Northwest and Pacific Rim markets.

The only currently operating commercial sawmill located within the Camp Navajo FSA is the recently installed Perkins Forest Products (PFP) facility at Williams. Located 22 miles from Camp Navajo, the PFP facility is forecast to produce 50,000 board feet of lumber/shift at full production.[144] In addition, Good Earth Power is working with investors to install a commercial sawmill at Williams that will be known as NewLife Forest Products (NLFP). NLFP is currently operating a sawmill at Heber (about 147 miles from Bellemont). The NLFP facility is forecast to produce approximately 300,000 board feet of lumber/shift at full production.[145]

If both sawmill enterprises achieve commercial operations at Williams, there may not be enough sawlog supply available on a long-term basis to support a sawmill operation at Camp Navajo.

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[142] Northern California OSB Plant Due Diligence Study, March 2018, The Beck Group.
[143] Ibid.
[144] Per discussions with James Perkins, Owner, Perkins Forest Products.
[145] Per discussions with Adam Cooley, Director of Sales and Manufacturing, New Life Forest Products.

Fuel Pellet Operation

Domestic production of fuel pellets has been focused on the residential heating market with sales of bagged product. In Arizona, the Forest Energy operation at Show Low (located 149 miles from Camp Navajo) has been producing about 30,000 tons/year of pellets since 1991. As natural gas prices have fluctuated over recent years, the wholesale[146] price has been quite low (~$4/MMBtu) which has impacted residential and industrial use of fuel pellets as a fossil fuel substitute. Homeowners are reluctant to invest in a wood fuel pellet stove and bagged fuel when natural gas heating is readily available and economically attractive.

Industrial production of fuel pellets targeting the renewable power generation markets in Europe and the Pacific Rim region are well established and growing. Fuel pellet exports from North America total about 2.1 million bone dry metric tons (BDMT)[147] in Q2 2018.[148] Approximately 1.5 million BDMT was exported from southeast U.S. ports (primarily to Europe) with about .6 million BDMT exported from Canadian ports (primarily to the Pacific Rim). Approximately 90% of U.S. pellet exports are currently delivered to the United Kingdom with the balance going to Belgium, Netherlands, and Italy. Approximately 76% of current Canadian pellet exports are delivered to Europe with 26% (about 160,000 BDMT) delivered to the Pacific Rim.

Additional industrial fuel pellet production is expected to enter commercial service in Canada by Q1 2019. Pinnacle Renewable Energy is building two facilities; 125,000 BDMT/year capacity facility in British Columbia and 400,000 BDMT/year capacity facility in Alberta. In the U.S., Enviva Partners, LP, expects to have its new 600,000 BDMT/year facility in North Carolina in commercial service by Q2 2019. Clearly the fuel pellet market is dynamic and expanding in direct response to global initiatives to replace fossil fuels used for energy production.

Findings

Collocation of complementary commercial enterprises has multiple advantages and should be pursued if a bioenergy production facility is planned for the Camp Navajo site. The most significant economic consideration is the potential for a ready onsite market for the long-term sale of power and heat.

Before collocation is pursued, analysis of the following should be conducted for enterprise(s) considered:

- Impact on raw material feedstock supply demand and pricing.
- Water demand requirements.
- Additional truck traffic and impacts on existing transport infrastructure.
- Long-term markets for products produced.
- Track record of enterprise and commercial viability of technology.

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[146] Per Energy Information Agency US Department of Energy data.
[147] One BDMT equals 2,200 pounds of dry wood fiber.
[148] As reported by Wood Resources International LLC.

R & D INCUBATOR FOR ENGINEERED FOREST PRODUCTS

ERI has expressed interest in siting a research and development incubator onsite at Camp Navajo to support emerging biofuels and bioproducts production technologies while collocating traditional forest products enterprises. This business cluster approach would facilitate innovative practices that would result in an economically successful business model that could be replicated at locations throughout the West. ERI has submitted a proposal to the USDA – Agriculture and Food Resources Initiative for funding to support initial startup of the bioeconomy business cluster research center at Camp Navajo. ERI expects a response back from the USDA in May 2019 regarding the outcome of the proposal. Appendix D is the Letter of Intent overview of the ERI proposal.

Discussion with ERI staff[149] confirmed a strategy to have a traditional forest products manufacturing facility as the anchor technology (e.g., sawmill, bioenergy facility). Ultimately ERI would like to site technologies that are complementary and have the ability to utilize all biomass generated as a byproduct of forest restoration and fuels reduction activities. The intent would be to locate enterprises across three general categories as noted below.

Traditional Business Class
Commercially proven technologies representing traditional conversion technologies:

- Sawmill
- Bioenergy
- Firewood
- Post and Pole

Near-Term Business Class
Emerging technologies likely to be in commercial service in the next three years:

- Biochar
- Next-generation Engineered Forest Products
- Torrefied Fuels
- Small-scale Gasification
- Renewable Natural Gas

Long-Term Business Class
Promising technologies that are likely to be in commercial service in the next 5 to 10 years:

- Nanocellulose Technologies
- Advanced Biofuels

If the Camp Navajo site is not available, ERI will consider siting the business cluster at Williams or Winslow.

In addition to collocation of traditional and promising technologies, ERI plans to implement an education and training program that will focus on jobs supporting forest feedstock collection and processing, as well as jobs supporting conversion technologies (sawmill, boiler operations). This

[149] Jeff Halbrook, Research Assistant and Dr. Han-Sup Han, Professor and Director, Forest Operations and Biomass Utilization.

education and training program would target coordinated efforts with the local community college (Coconino Community College) Vocational Technology education program.

Findings

Siting a research and development incubator and bioeconomy business cluster at Camp Navajo, as proposed by ERI, would add much value for the Flagstaff/Williams area. In addition, the siting of a training and education center with support from ERI and Coconino Community College would provide much value to the emerging forest products and bioenergy sectors.

RECOMMENDATIONS

Findings from this investigation confirm the viability of siting a commercial-scale bioenergy facility at Camp Navajo. Listed below are recommendations for AZDEMA to consider in support of a bioenergy project. Several of these recommendations are focused on discussions with specific agencies (Arizona Corporations Commission and DoD) that have the ability to effect policy that will impact the potential siting of a financially viable bioenergy facility at Camp Navajo. The recommendation to initiate a Request for Information, is included here so that AZDEMA can gauge potential private sector interest in the development of a commercial-scale bioenergy facility at Camp Navajo. Lastly, there is significant upside potential for Flagstaff and surrounding communities if NAU decides to locate a research, development and training center at Camp Navajo.

Arizona Corporations Commission

The success of a bioenergy facility at Camp Navajo is dependent upon an offtake agreement for the energy product produced (e.g., power, thermal energy, biomethane). A key opportunity is the sale of power to an Arizona utility. The Arizona Corporations Commission (ACC) has recently sponsored a series of meetings to discuss a biomass power generation policy statement that could facilitate a biomass power requirement in the state’s Renewable Energy Standard and Tariff (REST). The REST currently requires regulated utilities to provide 15% renewable power by 2025. As the large coal fired generating stations (Cholla and Navajo with a total of 3,350 MW of capacity) are considered for decommissioning, there may be an opportunity to provide dependable baseload (24/7) replacement power in the form of renewable biomass power.

Discussions sponsored by the ACC are considering between 60 and 90 MW of biomass power be included as a renewable resource mandate in the REST. The AZDEMA should consider active participation in the ACC sponsored meetings to alert the ACC of the potential to site a biomass power plant in northwestern Arizona at Camp Navajo.

Department of Defense

The Naval Observatory Flagstaff Station (NOFS) provides critical services for the DoD. The DoD is concerned that a new commercial-scale bioenergy facility located at Camp Navajo may impact NOFS’s mission. The DoD should consider sponsorship of an investigation to assess impacts (air emissions, thermal signature, infrared signature, water vapor signature) of a commercial-scale facility at Camp Navajo.

Request for Information

Should AZDEMA decide to move forward in support of a commercial-scale facility, a Request for Information (RFI) could be issued to gauge private sector interest in siting a bioenergy (e.g., biomass power, biomethane) facility at Camp Navajo. The RFI would target project developers, independent power producers and technology vendors that would consider a build/own/operate business model. Responses from the RFI would be analyzed, and responding firms would be ranked based on how their response best align with AZDEMA's mission.

Northern Arizona University

Location of a research and development campus focused on value-added uses of forest biomass at Camp Navajo has significant potential to help facilitate collocation of a bioenergy facility. In addition, a technical training and education center (possibly affiliated with Coconino Community College) would facilitate workforce training for the next generation of skilled workers involved with forest restoration and biomass utilization.

APPENDIX A. FEDERAL AGENCY RESPONSE TO POLICIES REGARDING FOREST BIOENERGY

October 24, 2018

The Honorable Richard C. Shelby
Chairman
Committee on Appropriations
United States Senate
Washington, D.C. 20510

The Honorable Patrick J. Leahy
Vice Chairman
Committee on Appropriations
United States Senate
Washington, D.C. 20510

The Honorable Rodney P. Frelinghuysen
Chairman
Committee on Appropriations
House of Representatives
Washington, D.C. 20515

The Honorable Nita M. Lowey
Ranking Member
Committee on Appropriations
House of Representatives
Washington, D.C. 20515

Dear Chairmen Shelby and Frelinghuysen, Vice Chairman Leahy, and Ranking Member Lowey:

On March 23, 2018, the President signed into law the *Consolidated Appropriations Act, 2018* (H.R. 1625), which included congressional direction and emphasis on the importance of the United States' forest sector to the energy needs of our country.[1] The U.S. Environmental Protection Agency (EPA), U.S. Department of Agriculture (USDA) and U.S. Department of Energy (DOE) will work collaboratively to meet the directives laid out by H.R. 1625. Consistent with this approach, Congress specifically directed EPA, USDA, and DOE, consistent with their missions, to jointly:

1. ensure that Federal policy relating to forest bioenergy
   a. is consistent across all Federal departments and agencies; and
   b. recognizes the full benefits of the use of forest biomass for energy, conservation, and responsible forest management; and
2. establish clear and simple policies for the use of forest biomass as an energy solution, including policies that—
   a. reflect the carbon-neutrality of forest bioenergy and recognize biomass as a renewable energy source, provided the use of forest biomass for energy production does not cause conversion of forests to non-forest use;

[1] https://www.congress.gov/115/bills/hr1625/BILLS-115hr1625enr.pdf

b. encourage private investment throughout the forest biomass supply chain, including in—
    i. working forests;
    ii. harvesting operations;
    iii. forest improvement operations;
    iv. forest bioenergy production;
    v. wood products manufacturing; and
    vi. paper manufacturing;
c. encourage forest management to improve forest health; and
d. recognize State initiatives to produce and use forest biomass

EPA, USDA, and DOE believe the goals of H.R. 1625 are consistent with and complementary to the President's 2017 Executive Order on *Promoting Energy Independence and Economic Growth*,[2] which emphasizes utilizing domestic sources of energy that are affordable, reliable, safe, secure, and clean. Consistent with the direction provided in the appropriations language, a longer-term time horizon should be considered when evaluating carbon emissions from forest biomass energy. A large body of peer-reviewed research papers, government funded reports, and other analyses demonstrate that different types of biomass can satisfy these principles. For example, the 2016 Billion-Ton Report (BT16) released by DOE concludes that between 2030 and 2040, the U.S. forestry, agriculture, and waste sectors could sustainably produce a billion tons of biomass annually for energy uses.[3]

In addition, other studies have found that demand for wood products, including specifically wood for energy, can serve to maintain or increase investment in forested land under current market and environmental conditions.[4] For example, research considering the impact of wood energy markets in the southeastern U.S. shows an increase in forest area, increased harvest, little change in forest inventory, and annual gains in forest carbon.[5]

The interagency approach to biomass energy provided by forests and other lands and sectors will be guided by an appreciation that forests and other lands and sectors are managed to provide multiple environmental, social, and economic benefits to our communities, while simultaneously contributing to U.S. energy independence and job creation. Maintaining healthy forests can bring jobs and stimulate investments in rural communities through the forests products sector, pulp and paper production, biomass power plants, combined heat and power facilities, and through small businesses providing fuelwood. Biomass removed during thinning and fuel treatment operations can be used to generate renewable energy, while simultaneously reducing the risk to forests from insects, disease, and fires. This aspect of forest management is especially important for our

[2] https://www.whitehouse.gov/presidential-actions/presidential-executive-order-promoting-energy-independence-economic-growth/
[3] https://www.energy.gov/eere/bioenergy/2016-billion-ton-report
[4] Tian, Xiaohui, Brent Sohngen, Justin Baker, Sara Ohrel, and Allen A. Fawcett. 2018. Will U.S. Forests Continue to Be a Carbon Sink? Land Economics February 2018. 94 (1): 97–113. ISSN 0023-7639.
[5] Abt, Karen L.; Abt, Robert C.; Galik, Christopher S.; and Skog, Kenneth E. 2014. Effect of policies on pellet production and forests in the U.S. South: a technical document supporting the Forest Service update of the 2010 RPA Assessment. Gen. Tech. Rep. SRS-202, Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 33 p.

western forests that continue to be faced with historic wildfire activity and forests across the country battling insect and disease epidemics. Forests and other lands also support outdoor recreation and tourism, bringing much needed income to rural communities. This type of economic stimulus allows rural communities to invest more in sustaining the ecosystems that support these communities and local industries.

There are a variety of EPA programs that address aspects of the production, processing, and consumption of biomass. Of most consequence to the use of biomass as a key energy source are recommendations on federal procurement of wood-containing products under EPA's Environmentally Preferable Purchasing Program and considerations for biomass use in conjunction with permitting of stationary sources under the Clean Air Act.

On April 23, 2018, EPA issued a policy statement making clear that in future regulatory actions biogenic CO_2 emissions from the use of biomass from managed forests will be treated as carbon neutral when used for energy production at stationary sources, provided the use of forest biomass does not cause conversion of forests to non-forest use.[6] In alignment with this policy statement, EPA is continuing to develop options that ensure the Agency's programs recognize the full benefits of biomass for energy and encourage the continued or potential growth of biomass use as a key part of our nation's energy supply. EPA will continue to address the use of biomass across these and other relevant Agency programs in a manner consistent with its mission, the directives within H.R. 1625, and other applicable legal authorities.

The USDA Forest Service works with partners at the federal, state, and local level, as well as forest landowners and conservation organizations, within a shared stewardship framework to increase the pace and scale of sustainable and responsible forest management. The Forest Service practices sustainable forest management on all federal lands within its jurisdiction. This activity is governed by numerous federal laws and regulations and is subject to a robust public participation process. USDA provides incentives via voluntary program delivery including technical outreach and assistance, financial assistance, and forestland protection. USDA also conducts and shares the results of forest research to provide the latest data, scientific information, and technological applications underpinning sound forest management and efficient wood products utilization.

For measures of forest conditions and services, USDA supports a comprehensive annual forest inventory program implemented by the U.S. Forest Service in partnership with States. The Forest Inventory and Analysis (FIA) program and associated programs provide insights into several topics relevant to the sector's sustainability including carbon sequestration, forest product sector and employment trends, biomass availability, land cover, land use change, pollutant effects, and fire risk.

USDA's Rural Development administers programs that use renewable biomass to produce electricity, steam, heating and cooling, and ready to use fuel for domestic use and export markets. Title IX of the Agricultural Act of 2014 authorized the use of biomass to make fuels, biobased products, and chemicals. Through these Title IX Energy Programs, USDA facilitated

[6] https://www.epa.gov/sites/production/files/2018-04/documents/biomass_policy_statement_2018_04_23.pdf

the use of combined heat and power and biomass boilers and are being used to make new fuels and plastics from renewable biomass harnessed sustainably from forests. The programs use loan guarantees, grants, and payments to enable business development and job creation in rural communities. Collaboration with EPA and DOE is an intrinsic element in implementing projects and program delivery.

DOE is authorized to conduct a program of research, development, demonstration, and commercial application for bioenergy. DOE's authority includes research, development, demonstration, and commercial application for biofuels and bioproducts, as well as cross-cutting research and development in feedstocks. DOE's research and development activities are working toward driving down the costs of biofuels and bioproducts.

Concurrently, EPA, USDA, and DOE will work consistent with their missions to establish clear and simple policies to reflect the carbon neutrality of forest bioenergy. EPA, USDA, and DOE will encourage the use of biomass as an energy solution, striving for consistency across federal policies and programs. Working together, the agencies can tap their respective expertise in harnessing the energy potential of this country, and their experience in protecting the environment and working with foresters, farmers and other land owners. Additionally, the agencies are committed to our ongoing work with all stakeholders, including industrial partners, states, tribes, local governments, and non-governmental organizations. EPA, USDA, and DOE believe that this interagency cooperation and continued stakeholder engagement will allow for the best available science and policy to be shared across the federal government. This process in turn will ensure that biomass plays a key role in addressing the energy needs of the United States consistent with our respective statutory mandates and in an environmentally and economically beneficial way.

If you have questions, please contact Troy Lyons, Associate Administrator for Congressional and Intergovernmental Relations, U.S. Environmental Protection Agency at (202) 564-5200, Robert MacGregor, Policy and Congressional Advisor, U.S. Department of Agriculture at (202) 260-8472, or Wayne D. Smith, Director of the Office of the Executive Secreteriat, U.S. Department of Energy at (202) 586-6207.

Sincerely,

Rick Perry

Andrew R. Wheeler
Acting Administrator
U.S. Environmental
Protection Agency

Sonny Perdue
Secretary
U.S. Department
of Agriculture

Rick Perry
Secretary
U.S. Department
of Energy

APPENDIX B. ARIZONA PUBLIC SERVICE REQUEST FOR PROPOSALS

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24 hour media hotline
602-250-2277
for members of the news media only.

May 7, 2018

aps issues rfp for forestry bioenergy resources

PHOENIX – Arizona Public Service Co. (APS) has issued a Forest Bioenergy Resources Request for Proposals (RFP). APS is seeking competitive proposals for projects that utilize biomass feedstocks from high-risk forest lands in Northern Arizona to generate capacity and energy, pipeline quality biogas, or other suitable products. APS will accept proposals for projects that will begin delivery in 2020 or later. The entire RFP process will be monitored and reviewed by a third-party independent monitor.

Information about proposal requirements and bidder registration is now available online at aps.com/rfp.

APS serves about 2.7 million people in 11 of Arizona's 15 counties, and is the Southwest's foremost producer of clean, safe and reliable electricity. Using a balanced energy mix that is nearly 50 percent carbon-free, APS has one of the country's cleanest energy portfolios, including both Palo Verde Generating Station and renewable energy. The company is also a proven leader in introducing technology and services that offer customers choice and control over their energy consumption. With headquarters in Phoenix, APS is the principal subsidiary of Pinnacle West Capital Corp. (NYSE: PNW).

APPENDIX C. SALT RIVER PROJECT REQUEST FOR PROPOSALS

Power Sources

SRP RFP seeks renewable projects, encourages bids with storage

January 22, 2018
Paul Ciampoli

Arizona-based Salt River Project Salt River Project has issued a request for proposals for 100 megawatts of new renewable energy, the public power utility said on Jan. 19.

The renewable energy projects selected in the process are intended to help SRP support interest in renewable energy from its business customers by expanding its customer-dedicated green energy programs for large commercial and industrial customers, SRP said.

Smaller size projects will be considered, but must have a minimum capacity of 25 MW.

Solar, wind, geothermal, and biomass projects will be considered. SRP is also encouraging bids for renewable energy projects that include a battery storage component.

SRP said that it is seeking green energy projects that can be delivered to SRP's transmission system and begin operation by the end of 2020. It will consider proposals for renewable facilities both in and outside of SRP's service territory in the greater Phoenix metropolitan area, including tribal lands.

The bids must also include a proposal for a long-term (25 year) power purchase agreement.

Renewable energy proposals in response to the RFP must be submitted to SRP by March 9, 2018. A short list selection will be issued by SRP by the end of April 2018.

Additional information about the RFP including instructions on how to register to submit proposals is available at srpnet.com/RenewableRFP.

SRP's Fiscal Year 2017 generation portfolio incorporates 838 MW of renewable energy resources, including solar, wind, biomass, geothermal and hydroelectric power.

APPENDIX D. NORTHERN ARIZONA UNIVERSITY LETTER OF INTENT FOR AN R & D INCUBATOR AT CAMP NAVAJO

Letter of Intent

Project Director:

Dr. Han-Sup Han, Professor/Director of Forest Operations and Biomass Utilization, Ecological Restoration Institute, Northern Arizona University, email: Han-Sup.Han@nau.edu

Task Area #1: Development of Forest Bioproducts Business Clusters

- Dr. David L. Nicholls. Forest Products Technologist, Pacific Northwest Research Station, USDA Forest Service, Alaska
- Dr. Patrick Rappold. Forest Health Extension Agent, The University of Arizona
- Dr. Ted Bilek, Economist, Dr. Carl J. Houtman ,Chemical Engineer, and Dr. Alan Rudie, Assistant Director, Forest Products Lab, USDA Forest Service, Wisconsin
- Dr. Nathaniel Anderson, Research Forester, Rocky Mountain Research Station, USDA Forest Service, Montana
- Mr. Jay Smith, Forest Restoration Director, Coconino County Public Works, Arizona

Task Area #2: Wood and Biomass Feedstock Production and Supply Chain Logistics

- Dr. John Sessions, Professor, Department of Forest Engineering, Resources, and Management, Oregon State University
- Dr. Andrew Sanchez Meador, Associate Professor, School of Forestry, Northern Arizona University
- Dr. Anil Kizha, Assistant Professor, School of Forest Resources, University of Maine
- Dr. Raffaele Spinelli, Research Scientist, National Research Council, Italy

Task Area #3: Enhancing Ecosystem Services and Rural Economic Impacts

- Dr. Yeon-Su Kim, Professor, School of Forestry, Northern Arizona University
- Dr. Deborah Page-Dumroese, Research Soil Scientist, Rocky Mt. Research Station, USDA Forest Service, Idaho
- Dr. Timothy Link, Professor, Department of Forest, Rangeland, and Fire Sciences, University of Idaho
- Dr. Carol Chambers, Professor, School of Forestry, Northern Arizona University

Task Area #4: Education, Training, Outreach, and Extension

- Dr. Iris Montague, Research Forester, Northern Research Station & Forest Product Marketing Unit, USDA Forest Service, Mississippi
- Dr. Tom Gallagher, Professor, School of Forestry and Wildlife Sciences, Auburn University, Alabama
- Mr. Darren McAvoy, Extension Specialist, Utah State University
- Mr. Jeffrey Halbrook, Research Associate, Northern Arizona University

APPLICATION:

- Program Area: Sustainable Agricultural Systems (A9201)
- Program Area Priority: The proposed project is focused on the expansion of biofuels and bioproducts production capacity through the development of sustainable feedstock supply chains and integrated business clusters that provide economic benefits to interconnected firms and local communities, as well as enhanced ecosystem services from managed forests.

Achieving a Sustainable Bioeconomy through Forest Bioenterprise Supply Chain Innovation in a Business Cluster Framework

Rationale: The development of new bioeconomy enterprises offers the opportunity to fully utilize woody biomass, expand the bioeconomy, improve ecosystem services, strengthen rural communities, and accelerate the rate of forest restoration across the US. Co-locating emerging biofuels and bioproducts production technologies with traditional technologies utilizing different types of biomass materials in a business cluster has the high potential for ground-breaking innovation through transdisciplinary synergy and vertical/horizontal integration. The benefits of clustering include more efficient flows of materials, lower capital investment requirements, and economic use of waste and byproducts, as well as diversifying employment opportunities in rural areas. The major barriers for realizing this promise of a sustainable bioeconomy are lack of economic competiveness of bio-based companies, especially those employing new technologies competing against well-established products. Furthermore, new cluster locations must be chosen carefully to consider proximity of supply, markets, infrastructure, availability of specialized labor, and supportive communities. We propose a new paradigm of forest operations to overcome these barriers and utilize currently underutilized or wasted raw materials by leveraging new technologies (e.g. nanocellulose technology and engineered products) together with traditional fiber and solid wood products at one or more sites in northern Arizona. A wide range of wood and biomass material types scattered across large landscapes often makes supply logistics prohibitively expensive, while new biomass conversion and wood product manufacturing processes frequently require feedstocks with narrow specifications. Sorting and pre-processing depots along the supply chain can increase transportability, improve material flow, maximize value recovery, accommodate storage and surges, and improve supply chain resilience, but benefits and costs must be carefully evaluated. We will develop innovative strategies to: 1) cluster bioeconomy businesses and 2) harvest, process and supply woody feedstocks efficiently and sustainably. After being developed/tested, the strategies can be expanded nationally to overcome the current barriers in raw material supply, product logistics, manufacture and marketing for biofuels and bioproducts, as well as traditional wood products.

Overall goal and specific objectives: Our overall goal is to develop a model bioeconomy business cluster consisting of enterprises that are vertically and horizontally integrated with one another to capture favorable economies of agglomeration in procurement, logistics, information, communication, taxes, labor and marketing. We hypothesize that the successful development of a sustainable bioeconomy using this approach will effectively support the 25-year goal of sustainable production of biofuels and bio-based products while enhancing forest ecosystem services such as water supply, fire resilience, recreation, biodiversity, and wildlife habitat.

Our specific short term objectives are to:

- develop a forest bioeconomy business cluster that realizes the potential for rural economic growth, and evaluate key factors determining the success of its development and operation compared to unclustered configurations;
- implement operations of centralized depots and optimized harvest and transportation logistics based on temporal and spatial forest inventory data, including demands for various types and qualities of wood and biomass feedstock by businesses within the cluster;
- evaluate impacts of developing the bioeconomy business cluster and accelerated forest restoration/fuel reduction treatments on rural economies and ecosystem services, such as

impacts on wildlife habitats, water quality and runoff dynamics as well as those resulting from biochar applications in managed forest ecosystems; and
- offer updated/targeted educational programs to 4-H youth, veterans, Native Americans and other rural and underserved populations to develop a vibrant workforce, and provide continuing education for professionals such as state-of-the-art knowledge on new bioeconomy opportunities and business practices, including operations and logistics.

Our specific medium and long-term objectives are to:
- develop sustainable bioenergy and bio-product industries and create rural prosperity and jobs through new and traditional technologies within rural areas of the US;
- establish cost-effective woody biomass supply systems that are adaptable to changing biomass inventories and demand for various feedstock materials;
- enhance ecosystem services including wildlife habitat, biodiversity, nutrient cycling, hydrological processes, and resilience to wildland fires and other disturbances; and
- develop new work forces and professionals in the bioeconomy, as well as train young scientists through their participation in research activities.

Approach: To achieve the project goal and objectives, we will take a holistic and systematic approach by bringing together and coordinating a transdisciplinary team of researchers, industry partners, and communities. The project is organized into four main task areas: 1) development of bioeconomy business clusters, 2) wood and biomass feedstock production and supply chain logistics, 3) ecosystem services and economic impact analysis, 4) education, training, outreach and extension. Each task includes multiple objectives cross-linked to other research tasks within this project and contributes to the successful accomplishment of the project's overall goal. While emphasizing an application of the project's outcomes at a national level, we will integrate and implement all tasks in relation to clusters located in northern Arizona to showcase how the business cluster and depot concepts can be successfully developed and applied to enhance bioenterprises. In the development of a new bioeconomy model, our approaches and efforts focus on directly quantifying the economic impacts of developing bioeconomy business clusters in selected locations considering existing community and workforce characteristics, and forestry-related infrastructure, as well as social and political aspects of cluster development. Environmental impacts will be evaluated through wildlife habitat improvements, hydrological modeling, and soil/hydrologic property assessments. Outreach and training will be a significant part of the project with the primary objectives of reaching underserved populations and assisting entrepreneurs and new workers to help build a sustainable bioeconomy within the US.

Potential impact and expected outcomes: The strategies to be developed in this project will support a combination of emerging and traditional bioenergy and biobased products, as well as a sustainable supply of biomass feedstock creating healthy forests with improved ecosystem services. The expected outcomes are: 1) strategies to develop bioeconomy business clusters that create a new bioeconomy in local communities, 2) efficient woody biomass feedstock production and supply chain logistics using centralized depot concepts, 3) maximized benefits and services from well-managed forests through successful implementation of forest restoration and fuel treatments in the forests, 4) expansion of the bioeconomy utilizing woody biomass, and 5) new forestry work forces supporting and expanding a biobased economy in the US.