FEASIBILITY ASSESSMENT FOR A COMMERCIAL SCALE WOODY BIOMASS CONVERSION FACILITY IN CENTRAL ARIZONA

Prepared for:
Upper Verde River Watershed Protection Coalition

Prepared by:
TSS Consultants
Sacramento, California

October 17, 2018
Final Report

This study was made possible by a Wood Innovations Grant
Administered by the US Forest Service, Region 3

ACKNOWLEDGMENTS

The authors wish to thank the following organizations for their significant efforts in support of this project. These include, but are not limited to:

Upper Verde River Watershed Protection Coalition Technical Advisory Committee
University of Arizona, Cooperative Extension
Sage Consulting
CDW Consultant Group

The TSS Consultants team includes:

Tad Mason, Project Manager
Jim Burk, Feedstock Supply Specialist
Frederick Tornatore, Chief Technical Officer
Matt Hart, Senior Consultant

ABBREVIATIONS

4FRI	4 Forest Restoration Initiative
AC	Activated Carbon
ADOT	Arizona Department of Transportation
APS	Arizona Public Service
ARRA	American Recovery and Restoration Act
AZDEMA	Arizona Department of Emergency and Military Affairs
BDT	Bone dry ton(s)
BLM	Bureau of Land Management
BNSF	Burlington Northern Santa Fe Railway
CFT	Compression Friction Treatment
EA	Environmental Assessment
EQIP	Environmental Quality Improvement Program
FIA	Forest Inventory Analysis
GIS	Geographic Information System
GT	Green Ton(s)
IRR	Internal Rate of Return
MBF	Thousand Board Feet
MW	Megawatt
NAU	Northern Arizona University
NRCS	USDA Natural Resource Conservation Service
NEPA	National Environmental Policy Act
PNVT	Potential Natural Vegetation Types
PJ	Pinyon and Juniper Grasslands
RCU	Rotary Compression Unit
SRFR	Sediment Retention Fiber Roll
SRP	Salt River Project
TPY	Tons Per Year
TSA	Target Study Area (Yavapai County)
TSS	TSS Consultants
USDA	United States Department of Agriculture
USFS	USDA Forest Service

TABLE OF CONTENTS

List of Tables

List of Figures

Appendices

INTRODUCTION

The Upper Verde River Watershed Protection Coalition is seeking alternative value-added utilization opportunities for excess woody biomass generated as a byproduct of watershed restoration, fuels reduction, and grassland restoration activities in the central/northern region of Arizona. Water availability and quality are a major concern for the Coalition, and wildfire represents the most significant threat to upland watersheds within the region.

In October 2016, TSS Consultants (TSS) completed a biomass feedstock supply availability assessment and found significant volumes of biomass feedstock technically available[1] from forest and grassland restoration activities conducted in central Arizona. If markets are available for biomass feedstocks, TSS found that the pace and scale of Pinyon Juniper (PJ) grassland treatments in Yavapai County could exceed 20,000 acres annually.

Alternative uses for this excess biomass (e.g., industrial-grade fuel pellets, torrefied fuel, bio-coal, biochar, storm water wattles) show promise for potential economically viable, commercial-scale production. Other value-added uses such as compost and landscape cover also have potential. Ultimately, biochar and storm water wattles with wood chips and biochar were selected as the most promising technologies based on the system's flexibility, state of the industry, and market potential. In addition, these technologies do not require significant water during manufacturing and conversion.

This feasibility assessment investigates the potential to site a commercial-scale biomass conversion facility within central Arizona that produces biochar and storm water wattles.

KEY FINDINGS

Summarized below are key findings generated as a result of this feasibility assessment.

Target Site Review

Using comprehensive site attribute screening criteria, TSS ranked 10 candidate sites. These are listed below with top-ranked sites posted first.

- Drake Cement
- Big Sky Industrial Park
- Eastridge Property
- Grapevine Industrial Park
- Yavapai-Prescott Indian Reservation
- Adjacent to Ruger Factory

[1] Over 119,000 bone dry tons per year technically available over a 40 year period assuming treatment of 24,000 acres per year and 7.65 BDT/acre of biomass removed.

- Sundog Transfer Station
- Old Santa Fe Lumber
- Southwest Forest Products
- Wishing Well

Feedstock Supply Chain Analysis

Summarized below are key findings from the feedstock supply chain analysis.

PJ Processing and Transport Contractors

TSS was encouraged by the interest level of operators willing to consider venturing into the PJ biomass processing and transport business in Yavapai County. Market demand for PJ biomass is the key driver for any future infrastructure investment. This initial supply chain analysis suggests that the infrastructure could be available if an economically viable market value was established for processed PJ biomass material. Market value of PJ biomass will be the key driver to expansion of existing processing and transport infrastructure.

All Ownerships Summary

Based on this analysis, private lands offer the most immediate opportunity to access woody biomass from PJ treatments within the Target Study Area (TSA). Most large ranch managers contacted during this analysis are currently conducting PJ treatments. Interspersed within these private ranch holdings are thousands of acres of State Trust lands, much of which are considered priority treatment areas. In order to optimize economies of scale, efforts to operate and remove PJ on these State Trust lands should ideally be conducted in conjunction with nearby private land treatments.

Following these private ranch holdings and State Trust lands, the areas covered by the South Zone Grassland Restoration Project on the Williams Ranger District of the Kaibab National Forest appear to offer the next most likely large-scale treatment project areas (specifically, the project area known as the Wash Tub Treatment area). TSS estimates that over 5,000 acres of the Wash Tub Treatment Area are located within the TSA and PJ biomass could be mechanically treated and removed.

Finally, the Chino Landscape Restoration Project, while still in the planning stages, should provide for larger-scale PJ treatment projects specifically in the southeast corner of the western half of the Chino Valley Ranger District. Considering the pace that this project has been progressing, TSS estimates it will not be ready for any project-scale operations for at least three years.

Feedstock Pricing

Discussions with contractors currently conducting PJ treatments within the TSA indicated that private landowners (primarily ranchers) are willing to provide only minimal compensation in the form of service fees ($/acre) for PJ removal or mastication to support grassland restoration activities. In one case, a mastication contractor indicated that $40/acre was the typical service fee paid by private landowners. Other landowners suggested a breakeven scenario, whereby the landowner would shear the trees and allow removal of the PJ stems at no cost. Existing operations now harvesting PJ material report payment of $38/BDT for processed PJ material delivered within about a 30-mile one-way transport distance, with little if any service fee provided by the landowner.

Based on this limited sample size, TSS believes that for any long-term PJ removal contract, the landowners will only consider a minimal service fee ($0 to $40 per acre). While the Natural Resources Conservation Service (NRCS) does provide funding to private landowners for PJ treatment and grassland restoration, budget constraints limit the treatment acreage to approximately 1,000 acres per year in Yavapai County.[2]

<u>Feedstock Cost Forecast</u>

TSS is aware of only one wood grinder operating within the TSA, a Vermeer horizontal grinder that is owned by Yavapai County. This machine is currently used by Yavapai County at the City of Prescott transfer station. With such a limited number of actual wood processors in the TSA, it was necessary for TSS to rely on the recent PJ grasslands research projects as well as anecdotal information from operators in other regions of the Southwest. Based on this information, TSS estimated that PJ material could be processed and delivered within a 40-mile one-way haul distance for $55 to $75 per BDT. Timber harvest residues and forest management material were estimated at $45 to $50 per delivered BDT.

<u>Stewardship Contracts</u>

While the South Zone Restoration Project is being prepared on the Williams Ranger District of the Kaibab National Forest, TSS learned that there are no immediate plans to pursue PJ treatments. The Kaibab NF's main focus is to prep and administrate the Four Forest Restoration Initiative (4FRI) project. At this time there are no plans by the US Forest Service to implement stewardship contracts (typically three to ten year duration) within the TSA.[3]

<u>Agreements with Ranches</u>

As previously discussed, private ranchers appear to be the most likely candidates to initiate any significant PJ removals in the short term (one to two years). Currently, most private ranches appear to be paying minimal service fees for PJ treatment. TSS estimates that any long-term contract with ranchers would result in service fees ranging from $0 to $40 per acre.

Value-Added Conversion Technology Review

Six value-added conversion technologies were considered:

- Industrial-grade fuel pellets

---

[2] Personal communications with Marques Munis, Rangeland Management Specialist, NRCS, Prescott Valley Field Office.
[3] The Prescott NF is working on stewardship contracts, but have no set schedule yet for implementation.

- Torrefied fuels
- Bio-coal (Enginuity Process)
- Biochar and activated carbon
- Fuel bricks
- Storm water wattles with wood chips and biochar

Eight assessment criteria were considered when conducting the value-added technology review:

- Commercial Availability
- Feedstock Requirements
- Job Creation
- Market Potential
- Water Supply and Wastewater Disposal
- Noise
- Relative Air Emissions
- Commercial Production

Findings from the conversion technology review are summarized in matrix format (see Table 9 on page 65). Biochar and storm water wattles with wood chips and biochar were selected as the most promising technologies based on the system's flexibility, state of the industry, and market risk.

Economic Analysis

TSS worked with biochar and wood chip wattle technology vendors to understand the capital costs and operational parameters of the proposed facilities at two scales of raw material (PJ feedstock) usage: 25,000 BDT/year and 100,000 BDT/year.

<u>Biochar Production</u>

Capital costs for the 25,000 BDT/year utilization, biochar production facility are estimated at $7,500,000 and the 100,000 BDT/year facility at $21,000,000.

With the baseline target of $800/BDT of biochar produced at the 25,000 tons per year (TPY) facility and $600/BDT of biochar at a 100,000 TPY facility, the price needed for an internal rate of return (IRR) that should attract investment (a minimum of 15% IRR) is consistent with wholesale market price considering the current market rate for biochar (up to $800 a bulk ton) in the West.[4] It should be noted, however, that the biochar market in the United States is still relatively small, and fluctuations in the price of biochar and accessibility to the marketplace could be challenging.

---

[4] Personal communication with Tom Miles, TR Miles Technical Consultants, July 28, 2018. Mr. Miles is also a Board Member of the International Biochar Initiative.

Wood Chip Wattle Production

Capital costs for the 25,000 BDT/year utilization, wood chip wattle production facility is estimated at $7,500,000 and the 100,000 BDT/year utilization facility is estimated at $20,000,000.

The baseline target for a 25,000 BDT per year facility was identified to be $3.00/ft and for a 100,000 BDT per year facility, the baseline target was identified to be $2.25/ft. The baseline target was determined using a minimum IRR of 15%, which should be sufficient to attract external investment. It should be noted that the majority of the wattle market uses straw-type filler with prices substantially below that of the identified wood wattle prices (~$0.70-$1.30/ft).[5] Understanding the demand for wood wattles in the region will be an important factor to consider prior to investment in a commercial-scale wattle manufacturing facility.

Biochar and Wood Chip Wattle Production

TSS also conducted an analysis to determine if simultaneous investment in a biochar facility and wattle facility was appropriate. Investing in a synchronized model incorporating both conversion technologies dramatically increases the financial risk. One of the most important decisions in this scenario is understanding how to optimize the flow of available wood.

With the additional levels of risk and uncertainty that comes with an investment in a biochar-wood chip wattle manufacturing line, TSS recommends that the biochar and wood wattle manufacturing systems be evaluated as completely independent business entities. Using this approach, each business would be able to stand alone with its own independent markets. If ultimately a premium for biochar-wood wattles is found, there could be value to having the two enterprises located adjacent to each other and possibly share infrastructure, labor and rolling stock.

Recommendations

Biochar and Wood Chip Wattle Production

Both the biochar and wood chip wattle markets in Arizona are not well defined. Discussions with wattle producers and Coalition representatives confirm that the current, relatively nascent market for wattles has significant upside potential. Both parties feel that a potential market opportunity for these products is mine reclamation activities within Arizona. Numerous mining operations focused on the extraction of copper, molybdenum, Portland cement, sand/gravel, pumice, perlite, salt, crushed stone and lime have been retired. The 2016 report to the governor by the Arizona State mine inspector noted that approximately 10,000 abandoned mines have been inventoried statewide.[6]

Considering the statewide market for mine reclamation, the Coalition is conducting a proof of concept trial to utilize PJ feedstock as raw material for wood chip wattles to be

[5] Market research conducted by TSS Consultants.
[6] 2016 Annual Report to the Governor, Joe Hart, Arizona State mine inspector.

deployed at various mine reclamation sites with grant funding from the US Forest Service. Trials will be conducted through a capstone research project with Northern Arizona University.

The capital expense for development of a wood chip wattle production facility is significant at $7,500,000. TSS anticipates that private financial markets will be reluctant to participate in debt financing of a facility producing a commodity with a relatively unknown end market. A critical step in achieving long-term debt financing is securing long-term offtake agreements for the commodity produced.

Monitor Bioenergy Initiatives

Several bioenergy initiatives are underway in northern Arizona including request for proposals issued by two large Arizona utilities: Salt River Project and Arizona Public Service. Both of these utilities are familiar with biomass power generation and the significant societal benefits (forest health, fuels reduction, employment) that result from deployment of commercial-scale facilities (such as Novo BioPower in Snowflake). The Coalition should continue to monitor the results of these requests for proposals.

In addition, the Arizona Department of Emergency and Military Affairs (AZDEMA); in conjunction with Coconino County, the Arizona Department of Forestry and Fire Management, and the USFS, is sponsoring a feasibility study to assess the potential opportunity to site a commercial-scale bioenergy facility at Camp Navajo. The Camp is strategically located on a major highway (Interstate 40) and a major class one railway (Burlington Northern Santa Fe) and has access to water and natural gas. PJ material from northern Yavapai County could be within economic transport distance of a bioenergy facility sited at Camp Navajo.

TARGET SITE REVIEW

TSS conducted a preliminary analysis for the siting of a woody biomass conversion facility in central Arizona. Utilizing Upper Verde River Watershed Protection Coalition ("Coalition") project team input, a total of 10 candidate sites were identified in jurisdictions including the County of Yavapai, City of Prescott, Town of Prescott Valley, and on the Yavapai-Prescott Indian Reservation.

Siting Attributes

Target site selection for a commercial-scale biomass conversion facility requires in-depth analysis of a site and its attributes to determine the benefits and challenges that each unique site offers. To examine and rank these candidate sites, TSS utilized coarse filters to focus the analysis. These filters are preliminary siting attribute screens as discussed in the Siting Attributes section below. Attributes were assigned site-ranking criteria and compared to one another in a Site Review Matrix format. Site rankings were then listed (high to low ranking) in a Site Scoring and Ranking summary table.

Nine siting attributes were considered for the target sites. These include:

- Current land use zoning.
- Environmental permitting ease.
- Space and property availability.
- Community support.
- Transportation systems adjacent to site (e.g., rail, highways, forest roads).
- Proximity to forest/range biomass feedstock.
- Proximity to watersheds at risk.
- Water availability.
- Electrical power and natural gas availability.

Candidate Sites

During the week of November 13, 2017, each of these sites were visited by TSS with the above siting attributes considered during the site visit. The 10 candidate sites include:

- Drake Cement (Yavapai County)
- Former Site of Southwest Forest Products (Yavapai County)
- Wishing Well (Yavapai County)
- Site adjacent to Ruger Factory (Prescott)
- Old Santa Fe Lumber (Prescott)
- Sundog Transfer Station (Prescott)
- Big Sky Industrial Park (Prescott Valley)

- Grapevine Industrial Park (Prescott Valley)
- Eastridge (Prescott Valley)
- Yavapai tribal land (Yavapai-Prescott Indian Reservation)

Brief descriptions of the sites, with photos, are presented below. Additional details can be found in the Site Analysis and Selection section below.

Drake Cement

Drake Cement is located 10 miles north of the community of Paulden in Yavapai County. The site has a dedicated access road from AZ Highway 89, as well as an active rail spur connected to the BNSF. The cement plant began operations in 2011. As can be seen in Figures 1 and 2, the site has considerable open space located to the east of the cement manufacturing facility itself.

Figure 1. Aerial Photo of Drake Cement Site

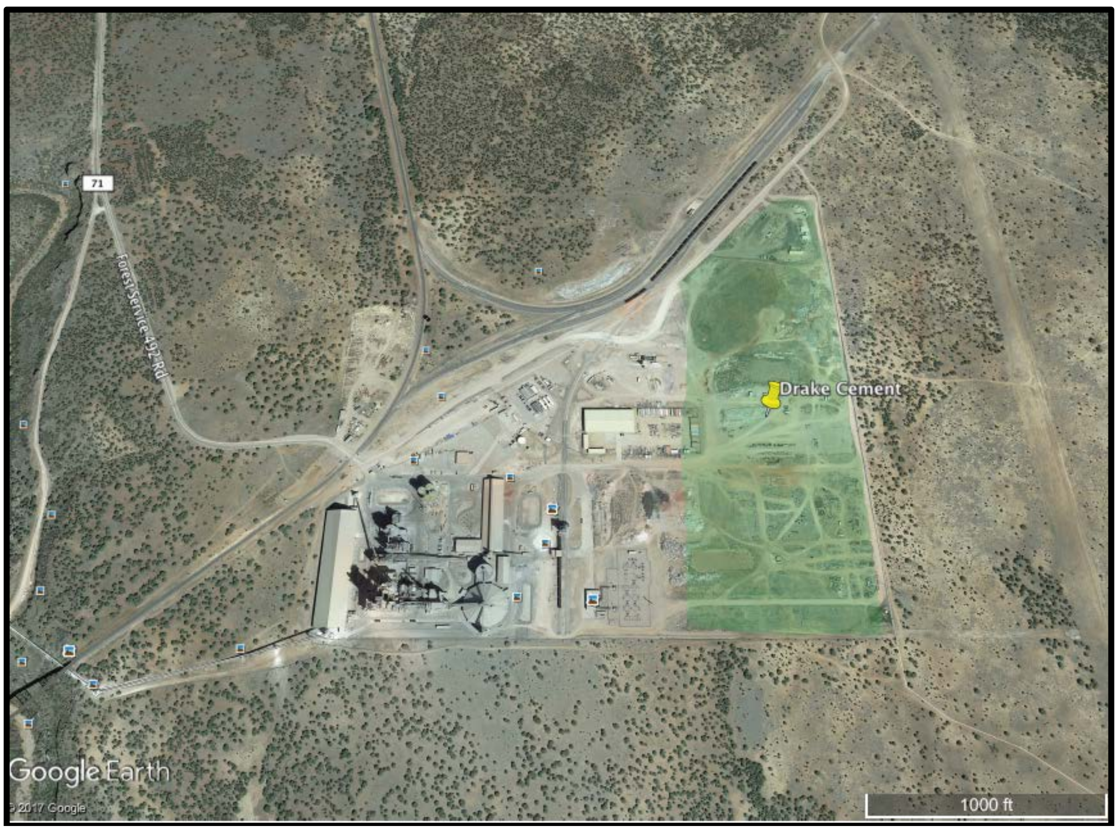


Figure 2. Photo of Drake Cement Site (East of Cement Plant)

<u>Former Site of Southwest Forest Products</u>

This site is located approximately seven miles west of Ash fork in Yavapai County on Route 66 with access to Interstate 40 (see Figure 3). It was the former site of Southwest Forest Products, with nearly all of that facility now removed from the site (Figure 4).

Figure 3. Aerial Photo of Former Southwest Forest Products Site

Figure 4. Photo of Former Southwest Forest Products Site

Wishing Well

This site is located just north of the community of Paulden (Yavapai County). It is readily accessible from AZ Highway 89 (Figure 5). It was formerly occupied by the Wishing Well Tavern (now defunct – see Figure 6)

Figure 5. Aerial Photo of Wishing Well Site

Figure 6. Photo of Wishing Well Site

Adjacent to the Ruger Factory

This site is currently zoned industrial land located across from the Ruger Firearms manufacturing facility on the northern side of the Prescott Municipal Airport (Figure 7). The land is currently unoccupied and unimproved (Figure 8), but with close access to AZ Highway 89.

Figure 7. Aerial Photo of Site Adjacent to Ruger Factory

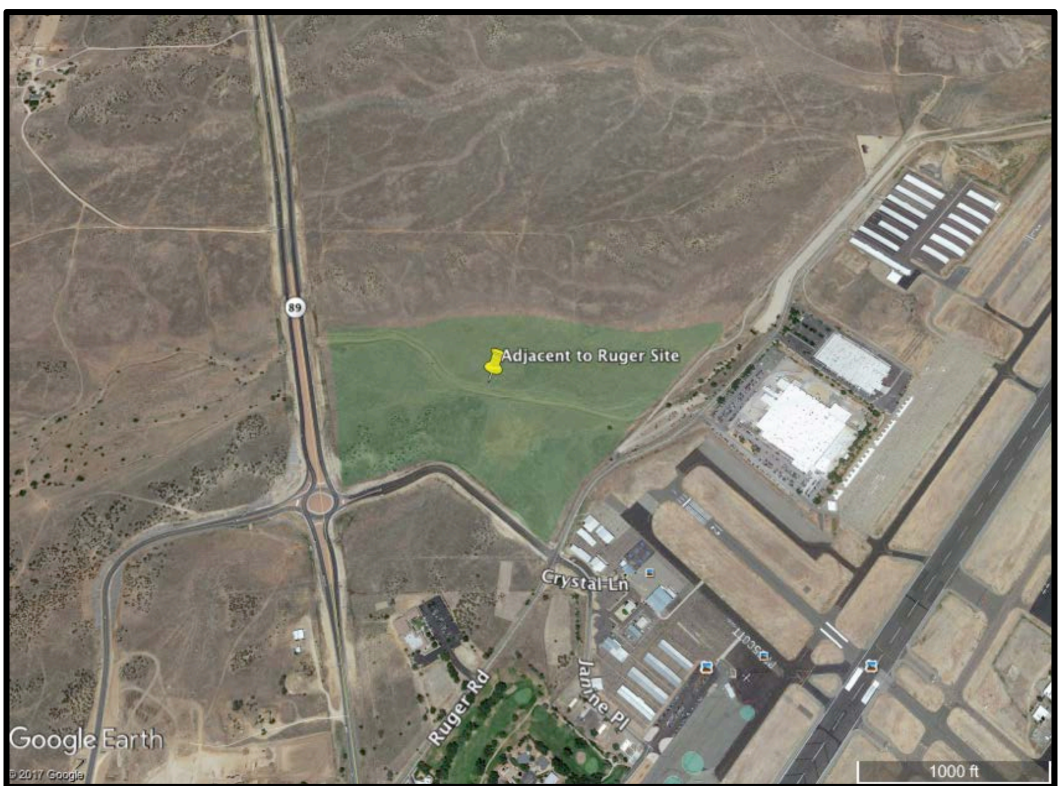
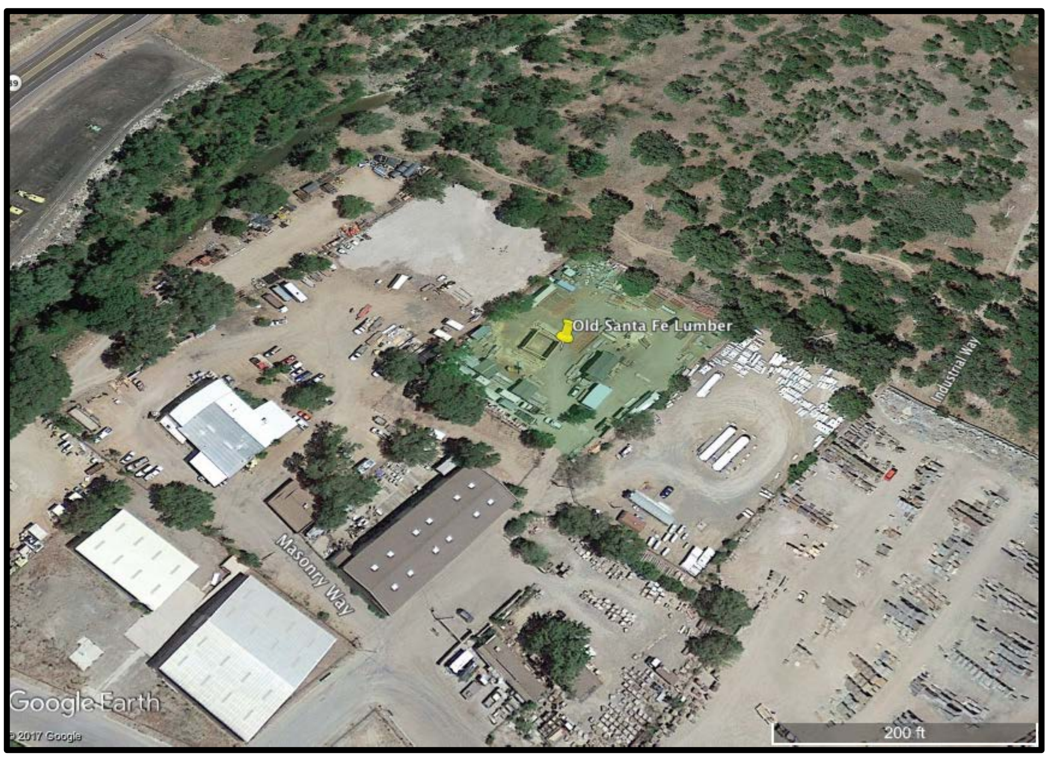


Figure 8. Photo of Site Adjacent to Ruger Factory

Old Santa Fe Lumber

This small site is located in the Sundog Business Park (Figure 9) located just off of AZ Highway 89 northeast of downtown Prescott.

Figure 9. Aerial Photo of Old Santa Fe Lumber Site



Sundog Transfer Station

This candidate site is located on a portion of the City of Prescott solid waste processing and transfer facility (Figures 10 and 11). It is located northeast of downtown Prescott with ready access to AZ Highways 89 and 69 via the Prescott Lakes Parkway.

Figure 10. Aerial Photo of Sundog Transfer Station

Figure 11. Photo of Sundog Transfer Station Biomass Stockpile Area

Big Sky Industrial Park

Located on the eastern side of the Town of Prescott Valley, this large industrial park still has considerable space for new facilities. The area indicated on Figure 12 is a relatively small portion of the Park. Flat land with full infrastructure is located in the Park (see Figure 13).

Figure 12. Aerial Photo of Big Sky Industrial Park Site

Figure 13. Photo of Big Sky Industrial Park Site

Grapevine Industrial Park

Located just to the southeast of Big Sky Industrial Park, this location is near the intersection of AZ Highways 69 and 89A (see Figure 14). The site is on flat terrain with easy road access (see Figure 15).

Figure 14. Aerial Photo of Grapevine Industrial Park Site

Figure 15. Photo of Grapevine Industrial Park Site

Eastridge

The large Eastridge property is located near central Prescott Valley with close access to AZ Highway 69 (see Figure 16). Currently, it is undeveloped land with some equipment storage (see Figure 17).

Figure 16. Aerial Photo of Eastridge Site

Figure 17. Photo of Eastridge Site

Yavapai Tribal Lands Sites 1 and 2

These two sites are across from each other along the connector road between Highway 89 and Highway 69 on the eastern edge of the Yavapai-Prescott Indian Reservation (see Figure 18) just south of the Sundog Business Park. The sites, now vacant land, were formerly the site of a wood products manufacturing plant (see Figure 19).

Figure 18. Aerial Photo of Yavapai Tribe Sites

Figure 19. Photo of Yavapai Tribal Site #1

Site Review and Scoring

As noted earlier, there were nine siting attributes used for the site review and analysis. To assist the Coalition in ranking the 10 sites examined for this task, Table 1 displays the site review criteria used to score, and ultimately rank, the sites.

Table 1. Site Review Scoring Criteria

Attributes	Scoring Criteria
Land Use Zoning	• 3 points – Site is zoned industrial by the respective jurisdiction. • 2 points – Site already has industrial uses, but new industrial use will require land entitlement review. Or, is in jurisdiction's General Plan as potential industrial land use. • 1 point – Not zoned industrial, but industrial uses could be granted through land use entitlement review.
Environmental Permitting Ease	• 3 points – Industrial uses on or adjacent to potential site, with infrastructure for potential use mostly in place. • 2 points – Industrial uses adjacent, or near, to potential site. • 1 point – Residential uses adjacent could cause siting and permitting issues.
Space and Property Availability	• 3 points – 10 or more acres potentially available. • 2 points – 5 to 10 acres potentially available. • 1 point – less than 5 acres.
Community Support	• 3 points – High, with considerable interest in siting a new facility. • 2 points – High, but with less interest in siting a new facility. • 1 point – Not well known.
Transportation Systems	• 3 points – Accessed by all-weather highway, with railroad siding. • 2 points – Accessed by all-weather highway or arterial roads, with no railroad siding. • 1 point – Access to highway restricted or constrained.
Proximity to Feedstock	• 3 points – Site is within PJ feedstock area. • 2 points – Site is adjacent to PJ feedstock area. • 1 point – Site is not tributary principal PJ feedstock area.
Proximity to Watershed at Risk	• 3 points – Site is located in upper watershed area. • 2 points – Site is located adjacent to upper watershed area. • 1 point – Site is not in, or tributary to, upper watershed area.
Water Availability	• 3 points – Adequate water supply available • 2 points – Adequate water supply available from wells. • 1 point – Water supply not readily available from any source.
Electric Power & Natural Gas Availability	• 3 points – Both adequate electrical power (up to 1 megawatt) and natural gas available at potential site. • 2 points – Adequate electrical power is potentially available, but no natural gas available. • 1 point – Adequate electrical power would have to be developed and natural gas access limited.

Tables 2 and 3 assign the scoring criteria values to each of the 10 sites using the nine siting attributes.

Table 2. Candidate Site Review Matrix

Site	Land Use Zoning	Permitting Ease	Space and Property Availability	Community Support	Transportation Systems	Sub-total
Drake Cement (Paulden) lat: 34.973072 lon: -112.382073	Yavapai County RCU (Rural Residential)	Compared to cement facility, should be easier. As not zoned industrial, though, land use entitlement will need review by County (and public review).	There appears to be over 10 acres of useable, flat land within the Drake Cement footprint.	Site is a major industrial use site. No nearby residences.	Good, paved highways, near AZ 89. Railroad siding at site.	
Score	**2**	**3**	**3**	**3**	**3**	**14**
Former site of Southwest Forest Products (Ash Fork) lat: 35.245608 lon: -112.625567	Yavapai County RCU	As not zoned industrial, land use entitlement will need review by County (and public review).	There appears to be over 10 acres of useable, flat land within the former sawmill and log storage area footprint.	Site was formerly a sawmill. There are residences within relatively close view of the site.	Good, paved highways. Near intersection with I-40. No railroad siding.	
Score	**2**	**1**	**3**	**2**	**2**	**10**
Wishing Well (Paulden) lat: 34.921667 lon: -112.452083	Yavapai County RCU	As not zoned industrial, land use entitlement will need review by County (and public review).	Site is less than 5 acres.	There are several residences directly across Old Highway 89 from the site.	Immediately adjacent to AZ 89. No railroad siding.	
Score	**1**	**1**	**1**	**1**	**2**	**6**
Adjacent to Ruger Factory (Prescott) lat: 34.657405 lon: -112.422822	City of Prescott Light Industrial	Industrial uses permitted, but will need a Similar Use Interpretation from the Prescott Community Development Director.	There appears to be over 10 acres of useable, industrially zoned land. It is currently undeveloped raw land.	Located within close proximity to the Prescott Airport, and there are no residences within view. It is currently undeveloped raw land.	City road to AZ 89. Access roads to highway adequate for large trucks. No railroad siding.	
Score	**3**	**2**	**3**	**2**	**2**	**12**
Old Santa Fe Lumber (Prescott) lat: 34.567272 lon: -112.452083	City of Prescott Light Industrial and General Industrial	Industrial uses permitted, but will need a Similar Use Interpretation from the Prescott Community Development Director.	Site is less than one (1) acre.	Industrial zoned property. Should have no community issues.	On AZ 89. Access roads to highway adequate for large trucks. No railroad siding.	

Site	Land Use Zoning	Permitting Ease	Space and Property Availability	Community Support	Transportation Systems	Sub-total
Score	**3**	**2**	**1**	**2**	**2**	**10**
Sundog Transfer Station (Prescott) lat: 34.579046 lon: -122.427745	City of Prescott General Industrial	Industrial uses permitted, but will need a Similar Use Interpretation from the Prescott Community Development Director.	Site is currently occupied by the City of Prescott Solid Waste Division.	Currently solid waste transfer yard. No residences nearby.	Adjacent to AZ 89. Access roads to highway adequate for large trucks. No railroad siding.	
Score	**3**	**2**	**2**	**2**	**2**	**11**
Big Sky Industrial Park (Prescott Valley) lat: 34.581591 lon: -112.2898	Town of Prescott Valley zoning M1 – Industrial, General Limited	Town of Prescott Valley Community Director confirmed potential uses are permitted.	The industrial park currently has unbuilt areas that can be combined (or split) to offer large properties for potential use – 10 acres plus.	Prescott Valley extremely supportive of new businesses.	Near intersection of AZ 69 and AZ 89A. Access roads to highway adequate for large trucks. No railroad siding.	
Score	**3**	**3**	**3**	**3**		**14**
Grapevine Industrial Park (Prescott Valley) lat: 34.577089 lon: -112.263183	Town of Prescott Valley zoning M1 – Industrial, General Limited	Town of Prescott Valley Community Director confirmed potential uses are permitted.	Town of Prescott Valley Community Development Dept. indicated two adjacent parcels are available. Total acreage is less than 5 acres.	Prescott Valley extremely supportive of new businesses.	Near intersection of AZ 69 and AZ 89A. Access roads to highway adequate for large trucks. No railroad siding.	
Score	**3**	**3**	**1**	**3**	**2**	**12**
Eastridge Property (Prescott Valley) lat: 34.581673 lon: -112.311759	Town of Prescott Valley zoning M1 – Industrial, General Limited	Town of Prescott Valley Community Director confirmed potential uses are permitted.	More than 10 acres can be made available.	Prescott Valley extremely supportive of new businesses.	Accessible from AZ 69. No railroad siding.	
Score	**3**	**2**	**3**	**3**	**2**	**13**

Site	Land Use Zoning	Permitting Ease	Space and Property Availability	Community Support	Transportation Systems	Sub-total
Yavapai Tribal Land Sites 1 and 2 lat: 34.558172 lon: -112.434645	Tribal Land Use Master Plan is being updated and zoning will likely be light-medium industrial	Site was previously contaminated, now cleaned up. Use permitting via the Yavapai Tribal Planning Department.	One of the two subject parcels is slightly over 5 acres. Second parcel is slightly under 5 acres.	Yavapai Tribe very dedicated to developing additional business ventures within Reservation. Sites are adjacent to their Sundog Business Park.	Located on connector road between AZ 69 and AZ 89. No railroad siding.	
Score	**3**	**2**	**2**	**3**	**2**	**12**

Table 3. Candidate Site Review Matrix (Part Two)

Site	Proximity to Feedstock	Proximity to Watersheds @ Risk	Water Availability	Electrical Power and Nat. Gas Availability	Subtotal	Total
Drake Cement (Paulden) lat: 34.973072 lon: -112.382073	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	Good as large cement plant sited nearby.	Ample electric power supplies at site as well as natural gas.		
Score	**3**	**3**	**2**	**3**	**11**	**25**
Former site of Southwest Forest Products (Ash Fork) lat: 35.245608 lon: -112.625567	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	Unknown, but did have sawmill previously which needs water supply.	Electric power appears inadequate. Natural gas nearby but is a transmission line, not a distribution line.		
Score	**3**	**3**	**1**	**1**	**8**	**18**
Former site of Wishing Well (Paulden) lat: 34.921667 lon: -112.452083	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	City-supplied water.	Electric power appears inadequate. Natural gas not available.		
Score	**3**	**3**	**2**	**1**	**9**	**15**
Adjacent to Ruger Factory (Prescott) lat: 34.657405 lon: -112.422822	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	City-supplied water.	Adequate electricity available. Natural gas available.		
Score	**2**	**2**	**3**	**2**	**9**	**21**
Old Santa Fe Lumber (Prescott) lat: 34.567272 lon: -112.452083	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	City-supplied water.	Adequate electricity available. Natural gas available.		
Score	**2**	**2**	**3**	**3**	**10**	**20**
Sundog Transfer Station (Prescott) lat: 34.579046 lon: -122.427745	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	City-supplied water.	Adequate electricity available. Natural gas available.		

Site	Proximity to Feedstock	Proximity to Watersheds @ Risk	Water Availability	Electrical Power and Nat. Gas Availability	Subtotal	Total
Score	**2**	**2**	**3**	**3**	**10**	**21**
Big Sky Industrial Park (Prescott Valley) lat: 34.581591 lon: -112.2898	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	Town-supplied water.	Adequate electricity available. Natural gas available.		
Score	**2**	**2**	**3**	**3**	**10**	**24**
Grapevine Industrial Park (Prescott Valley) lat: 34.577089 lon: -112.263183	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	Town-supplied water.	Adequate electricity available. Natural gas available.		
Score	**2**	**2**	**3**	**3**	**10**	**22**
Eastridge Property (Prescott Valley) lat: 34.581673 lon: -112.311759	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	Town-supplied water.	Adequate electricity available. Natural gas available.		
Score	**2**	**2**	**3**	**3**	**10**	**23**
Yavapai Tribal Land Sites 1 and 2 lat: 34.558172 lon: -112.434645	Site is in proximity to adequate feedstock.	Site is in proximity of watersheds at risk.	City-supplied water.	Adequate electricity available. Natural gas available.		
Score	**2**	**2**	**3**	**3**	**10**	**22**

Candidate Site Ranking

Using the scoring criteria in Table 1 and applying it to the candidate sites in Tables 2 and 3, the following table (Table 4) summarizes the candidate sites ranking.

Table 4. Candidate Site Ranking

Site	Score	Ranking
Drake Cement	25	**1**
Big Sky Industrial Park	24	**2**
Eastridge Property	23	**3**
Grapevine Industrial Park	22	**4**
Yavapai-Prescott Indian Reservation	22	**4**
Adjacent to Ruger Factory	21	**5**
Sundog Transfer	21	**5**
Old Santa Fe Lumber	20	**6**
Southwest Forest Products	18	**7**
Wishing Well	15	**8**

FEEDSTOCK SUPPLY CHAIN ANALYSIS

Using findings from the October 2016 biomass feedstock supply availability assessment,[7] TSS conducted a biomass feedstock supply chain infrastructure analysis to confirm current status of feedstock utilization and potential to ramp up activities to meet commercial-scale market demand.

During the week of December 11, 2017, TSS staff traveled to northern Arizona and met with state and federal land managers as well as private sector landowners, natural resource managers and logging contractors. Utilizing information obtained through these contacts, TSS prepared the following feedstock supply chain analysis.

Current Feedstock Processing and Transport Infrastructure

As was indicated in the 2016 biomass feedstock supply availability assessment, commercial uses for PJ biomass in the TSA (Yavapai County) are limited. As such, it is not surprising that little commercial-scale PJ feedstock processing and transportation infrastructure was encountered within Yavapai County.

Feedstock Processing Infrastructure

The primary PJ reduction operation, of any significant commercial size, was a mastication contractor operating in the Chino Valley. Matt Monahan of Monahan Thinning, estimated that with his five masticating machines, he can effectively treat 40 acres per day. In 2017, Mr. Monahan estimated he would thin PJ on an estimated 10,000

[7] Biomass Feedstock Supply Availability Assessment for Yavapai County, TSS Consultants, October 2016.

acres. Obviously, the mastication process does not extract or utilize woody biomass material; however, Mr. Monahan suggested that if the economics were satisfactory, he would consider converting his mastication equipment to facilitate harvest and removal of PJ stems.[8] In addition, he would incorporate an industrial-sized grinder to process the PJ into wood chips.[9]

In addition to Monahan Thinning, TSS contacted Kenneth Cox and Cass Faykus of Northern Arizona Procurement Company (NAPCO). NAPCO is currently operating on the Four Forest Restoration Initiative (4FRI) project near Flagstaff. NAPCO also has experience harvesting and processing PJ species in Texas. NAPCO views the PJ harvesting operation as a way to extend their operating season when winter weather forces them out of the higher elevation ponderosa pine areas of the 4FRI project. In addition, NAPCO has access to five grinders and numerous chip trailers that they would consider relocating from Texas if the market for PJ biomass were to develop in Yavapai County. Kenneth Cox also indicated that the company is working on an innovative shear head design for use on PJ dominated landscapes. TSS has requested NAPCO provide an estimated price per ton for shearing, collecting and processing PJ in Yavapai County.[10]

Finally, TSS also traveled to eastern Arizona and met with Allen Reidhead of Tri-Star Logging. TSS believes that Tri-Star Logging is the largest PJ removal contractor in the Southwest, processing an estimated 600 acres of PJ per month. Tri-Star operates three CBI grinders and can produce 20 loads per day of processed PJ biomass fuel. Tri-Star currently transports all PJ biomass production to Novo BioPower, a 27 MW biomass power plant located in Snowflake. Mr. Reidhead indicated that market price for this fuel is around $38 per Bone Dry Ton (BDT) delivered within a 30-mile haul distance of Novo BioPower with little, if any, subsidy from landowners for removing the PJ. Tri-Star indicated a willingness to consider relocating part of their operation to Yavapai County if a market opportunity were to develop.

Table 5 provides a summary of the current contractors operating in and adjacent to Yavapai County with a willingness to consider PJ harvesting and processing in the county.

[8] Replace mastication attachment with shearing attachment.
[9] Four inch minus chips.
[10] NAPCO has yet to respond.

Table 5. Operators Interested in Producing PJ Feedstock Supply

Company	Location	PJ Harvesting Experience	Equipment Mix	Estimated Capacity BDT/Year	Estimated Cost ($/BDT) FOB Truck)
Monahan Thinning	Chino Valley, AZ	Mastication w/o removal	(4) Rubber-Tired Hydro-Axes (1) Prentice (all with masticator heads)	10,000 acres/year approx. 75,000 BDT/year	Unknown
NAPCO	Flagstaff, AZ	Yes East Texas	(5) Grinders, designing custom shear head	5 to 10 acres/day per machine	Unknown
Tri-Star Logging	Snowflake, AZ	Yes Eastern Arizona	(3) CBI Grinders (1) Bandit Chipper	600 acres/month approx. 4,500 BDT/month	$38/BDT (includes 30-mile one-way transport cost)

Truck Transport Infrastructure

In addition to the harvesting and processing infrastructure, transportation infrastructure is also important to the successful movement of this woody biomass material. A key consideration for the transportation infrastructure are the weight limit restrictions enforced by the state of Arizona. Arizona has historically used an 80,000 pound gross vehicle weight limit. This translates into a maximum net payload of around 25 tons (assuming moisture content of the biomass is above 35%). If the moisture content drops below 30%, the maximum payload can be difficult to obtain simply due to the volumetric limit of the trailer. In order to improve the load capacity, a higher volume trailer (more cubic carrying capacity) is often utilized. This can be accomplished by increasing the length of the trailers from the standard 45-foot to the longer 53-foot or by utilizing a possum-belly trailer design. As the name implies, the possum-belly trailer utilizes additional hauling capacity extended beneath the normal trailer bottom frame. Figure 20 is an example of a high capacity possum belly trailer.

Figure 20. Example of High Capacity Chip Trailer

Currently, at least one trucking company, Otto Logistics, LLC, has been using these types of trailers to haul woodchips from the 4FRI project to mulch operations in the Phoenix area. Alan Otto, owner of the company, has indicated an interest in providing trucks for hauling PJ biomass throughout Yavapai County.[11] With over 200 trucks and trailers, Otto Logistics is one of the largest trucking firms in Arizona.

As part of the Healthy Forest Initiative, the Arizona Department of Transportation (ADOT) has published the Healthy Forest Guide for Transporters.[12] This guide outlines procedures for haulers to apply for an overweight permit to transport this type of forest-derived fuel. Appendix A provides a copy of this guide. According to Jennifer Cannon, Manager, Maintenance Permits Services, ADOT, this overweight permit increases the gross vehicle weight limit from 80,000 to 90,800 pounds on Arizona State Highways. Federal Interstate Highways are not included and county roads require local county exemptions. Ms. Cannon indicated that if the UVRWPC can make the case that PJ treatments are needed to protect the watershed and reduce fuel loading and that increasing the weight limit will allow for accelerated treatment of these areas, then an exemption should be possible. It is likely that such a case can be made for Yavapai County and that similar weight limit adjustments implemented in Navajo County should be applicable for UVRWPC projects. Considering the fact that transportation costs are often the highest single cost component in the woody biomass supply chain, a 13.5% increase in net payload (90,800 pounds vs. 80,000 pounds) would be critical for cost-effective PJ biomass feedstock transport in Yavapai County.

---

[11] Personal communications with Alan Otto, January 2018.
[12] ADOT Healthy Forest Guide for Transporters, Arizona Department of Transportation. Dec 8, 2014.

During this analysis, TSS learned that Tri-Star Logging is participating in the Healthy Forest Initiative process to facilitate transport of PJ biomass to Novo BioPower in Snowflake. With this permit, Tri-Star has begun to utilize possum-belly chip vans in an effort to increase their load volume and reach a gross vehicle weight of 90,800 pounds. Allen Reidhead of Tri-Star estimates that the possum-belly trailers will allow a payload of 20 BDT per load at the increased maximum gross payload of 90,800 pounds. This is a significant increase in Tri-Star's previous average payload of approximately 15 BDT per load when using 45-foot chip vans.

In addition to Otto Logistics and Tri-Star, TSS also talked with Kenneth Cox of NAPCO regarding transportation infrastructure. Mr. Cox indicated that NAPCO has access to numerous chip vans (from its Texas operations), which could be available as part of a PJ supply chain operation in Yavapai County.

<u>Rail Transport Infrastructure</u>

The Drake Cement facility near Paulden has a rail spur on site connected to the BNSF Railway. TSS contacted Ean Johnson, Economic Development Manager with the BNSF to discuss potential rail transport of PJ biomass. While Drake's primary use of the rail spur is to receive shipments of coal, TSS was informed that there might be excess capacity that could be utilized for loading of woody biomass into railcars. Freight rates and other charges have not been forthcoming from Mr. Johnson. Summarized below are key questions posed to Mr. Johnson:

- Rail rates from Drake to Long Beach and "drop and pull" rate?
- Bulk material rail car availability?
- Bulk density and rail car capacity – estimated price per ton?
- Drake Cement rail car handling charges?

<u>Conclusions</u>

TSS was encouraged by the interest level of operators willing to consider venturing into the PJ biomass processing and transport business in Yavapai County. Market demand for PJ biomass is the key driver for any future infrastructure investment. This initial supply chain analysis suggests that the infrastructure could be available if an economically viable market value was established for processed PJ biomass material. Market value of PJ biomass will be the key driver to expansion of existing processing and transport infrastructure.

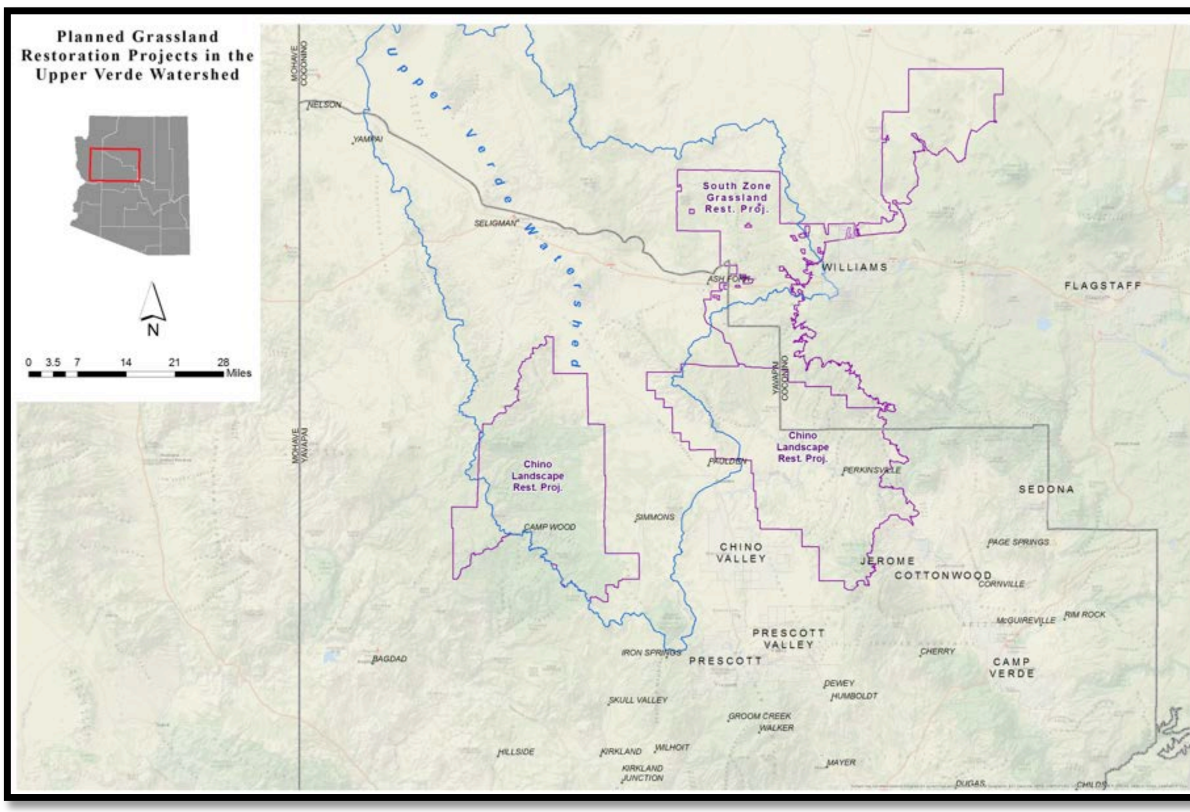
Forest and Grassland Restoration Projects Planned

As was determined in the UVRWPC Phase I Feedstock Supply Availability Assessment, the largest PJ grasslands manager within Yavapai County is the USDA Forest Service (USFS) with almost 550,000 acres or 56% of the total PJ woodlands acreage. As such, a major portion of grassland restoration efforts within Yavapai County are focused on these lands. While private lands make up almost 250,000 acres, or more than 25% of PJ grasslands in the county, these lands are difficult to analyze. Many private ranch owners are reluctant to discuss their PJ grassland restoration project plans and implementation efforts. Although in most cases these private landowners are intent on eliminating PJ from their grasslands, many were not responsive to TSS inquiries.

USDA Forest Service

With over 56% of the PJ grasslands under USFS management within Yavapai County, TSS believes that future efforts to develop this feedstock will require close coordination with this agency. Over 1.2 million acres of the Prescott National Forest lies within the county. However, based on meetings and discussions with USFS personnel, the Kaibab National Forest may offer the most immediate opportunity to develop PJ feedstocks. Figure 21 provides an overview of the planned USFS Grassland Restoration Projects within Yavapai County.

Figure 21. USFS Grassland Restoration Projects Planned

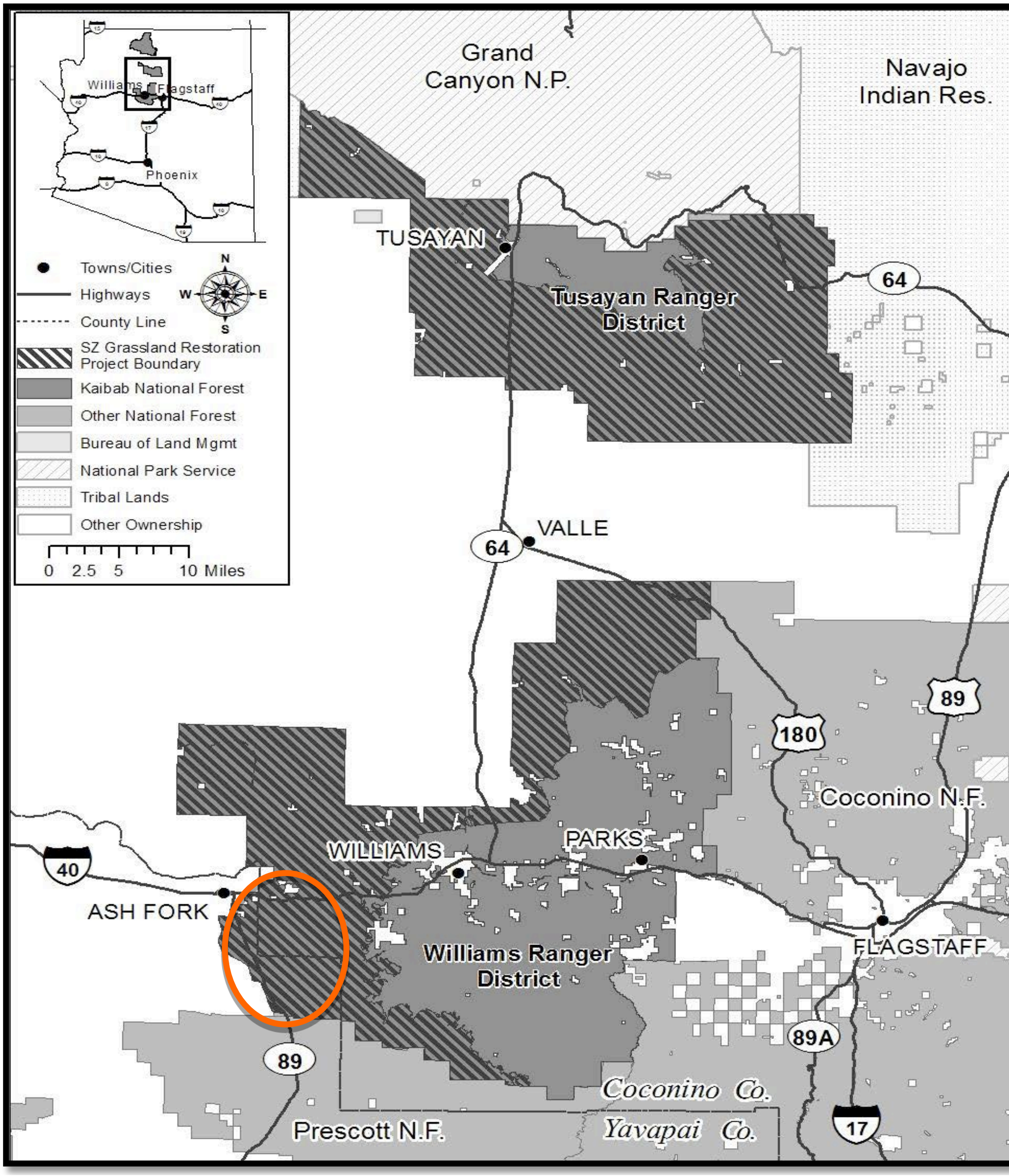


The Kaibab NF has long been involved in PJ grassland restoration work. The Williams Ranger District of the Kaibab NF has been actively treating PJ grasslands for more than a decade. It is estimated that since 2006 they have treated over 10,000 acres.[13] This past year, the Williams Ranger District and Tusayan Ranger District on the Kaibab NF completed the South Zone Grasslands Restoration Project Environmental Assessment.

[13] Personal communications with Roger Joos, Wildlife Biologist, US Forest Service, formerly with the Kaibab NF, Williams RD.

This ambitious project covers approximately 550,000 acres. The Forest Service estimates that approximately 63,000 acres of PJ grasslands have been identified for mechanical treatment within the Study Area.[14] The map in Figure 22 provides an overview of the South Zone Grasslands Restoration Project sites.

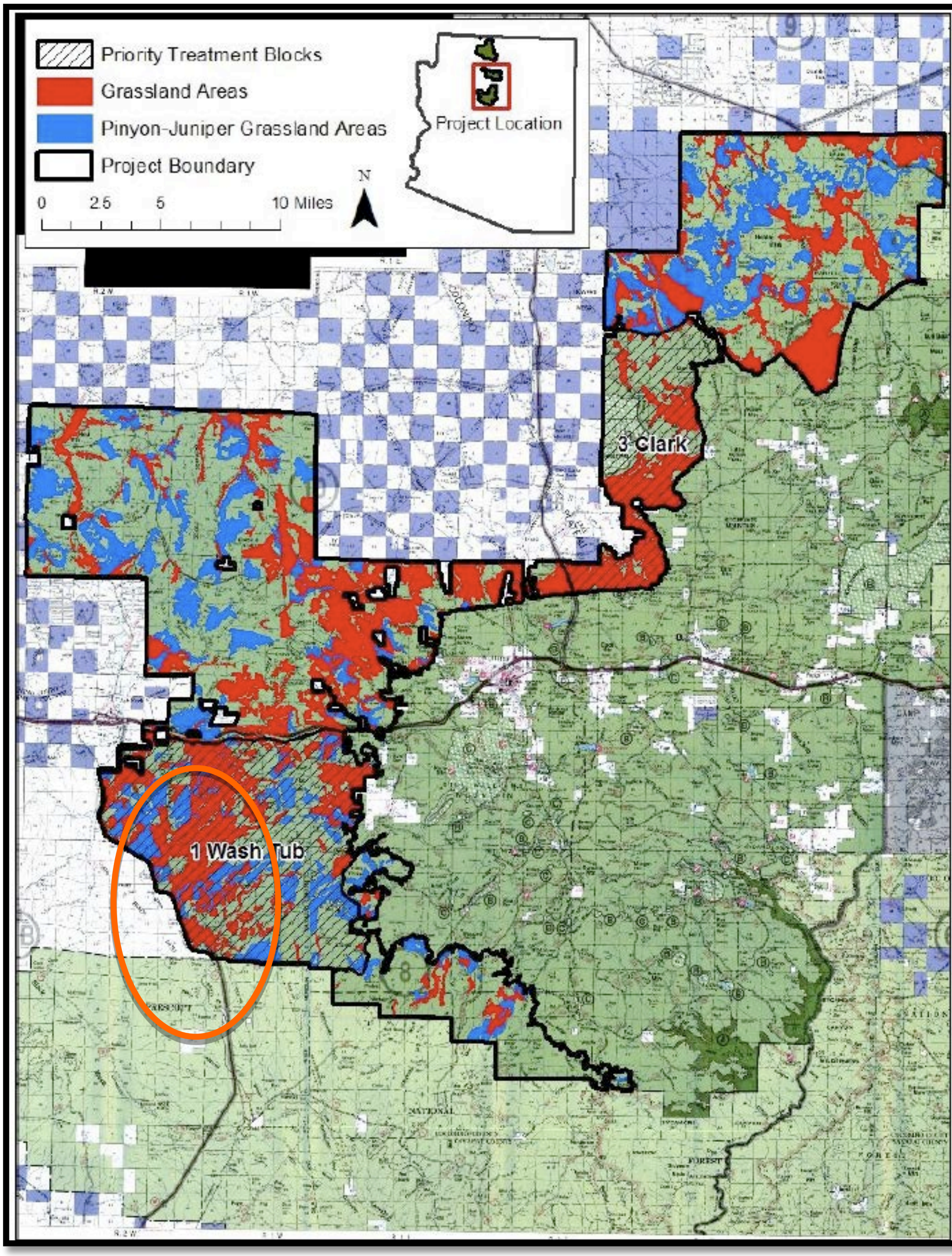
Figure 22. South Zone Grasslands Restoration Project Area



[14] South Zone Grassland Restoration Project, Preliminary Environmental Assessment. US Forest Service, Kaibib National Forest, August 2016.

As the map in Figure 22 shows, a small portion (circled in orange) of this treatment area is located just south of the town of Ash Fork and is bordered by Highway 89 on the west and lies within the TSA. TSS believes this area of the South Zone Project may be one of the first areas available for PJ removal activities. During meetings with Williams Ranger District personnel, TSS was informed that archeological review and clearance has been conducted on much of the district and that project work could begin once funding is provided. According to the Environmental Assessment report (EA), PJ treatments would be implemented using a phased approach. One of the first priority treatment areas is the Wash Tub treatment block partially located within the TSA. Figure 23 provides a map showing the Wash Tub treatment block (highlighted in orange).

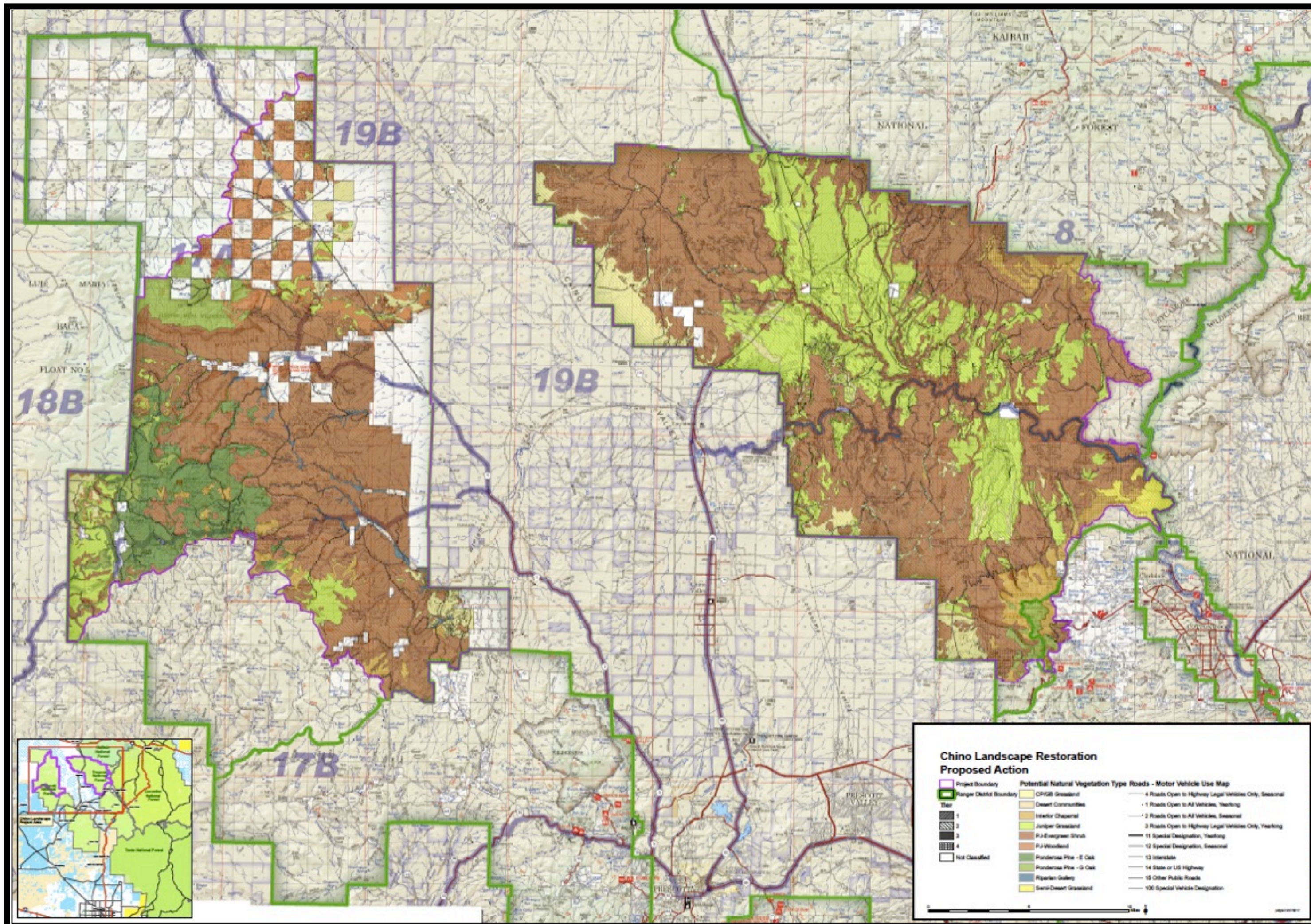
Figure 23. Wash Tub Treatment Site



The USFS estimates that there are approximately 10,959 acres of PJ grassland within the Wash Tub treatment block. TSS estimates that more than half of this acreage lies within the TSA. TSS applauds the Kaibab National Forest for having the foresight when preparing the EA to include the option for commercial treatments (PJ removal) on these lands in the event that a regional biomass facility (or other private entities express interest in utilizing project generated wood waste) were to be developed. Obviously, the Wash Tub block represents a small portion of the total PJ grassland area within the TSA, but it has been designated as the top priority treatment area within the South Zone Grassland Restoration Project EA. Currently, the Williams Ranger District staff has been focused on preparation and layout of the 4FRI project so no timeframe has been provided for activities within the Wash Tub block. However, TSS would expect to see some effort in this regard within the next one to two years.

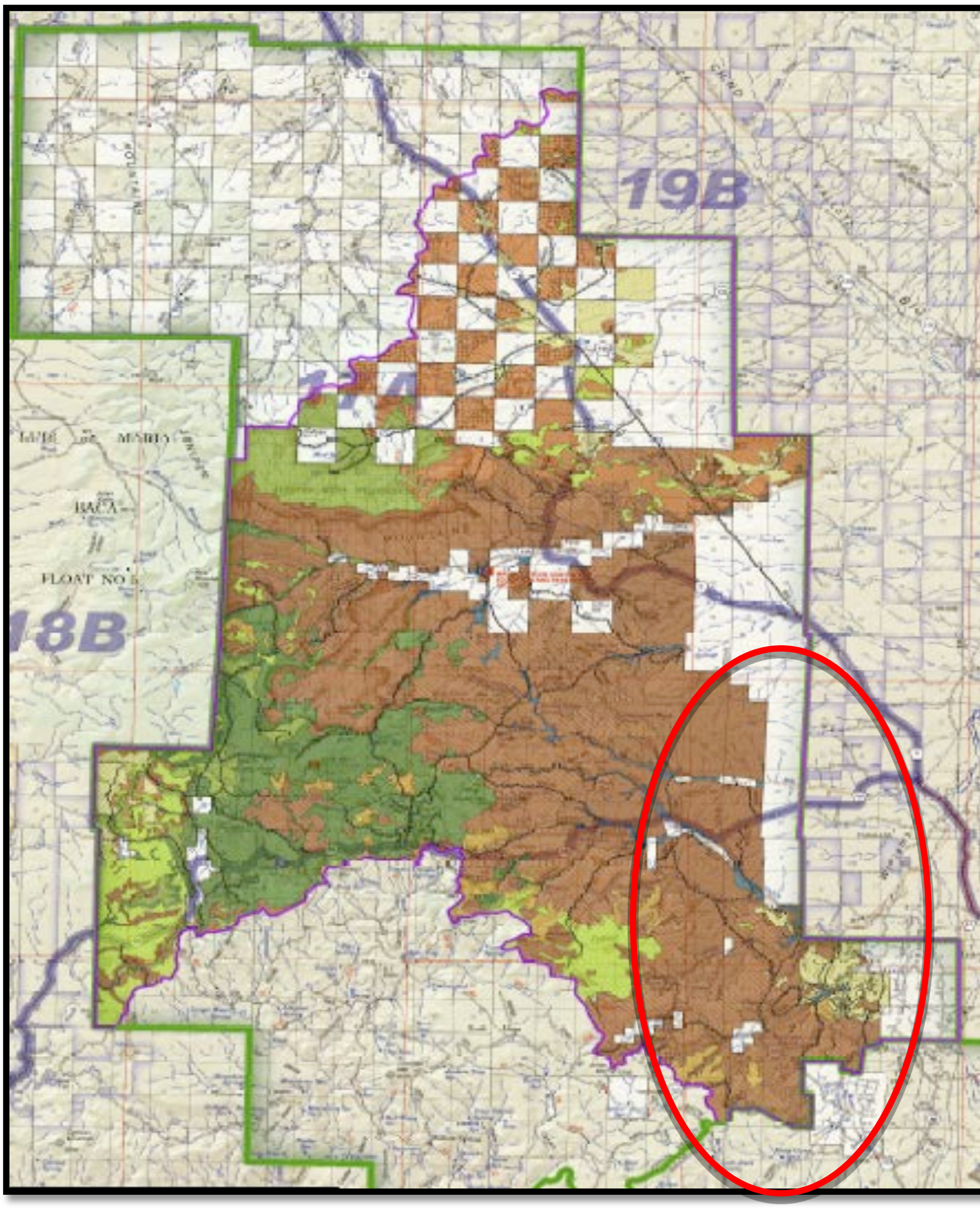
While not nearly as far along as the South Zone Grassland Restoration Project, the Prescott National Forest has been involved with the Chino Landscape Restoration Project for several years. This project area encompasses almost 485,000 acres within the northern portion of the Prescott National Forest. Over 99% of the project area (about 480,000 acres) is located in the Chino Valley RD and is within or tributary to the Upper Verde River watershed. Figure 24 provides an overview map of the project area.

Figure 24. Chino Landscape Restoration Proposed Project Area



Priority treatment areas have been designated as Tier 1 through Tier 4, with Tier 1 being first priority. The PJ Evergreen Shrub and PJ Grassland Potential Natural Vegetation Types (PNVT) make up almost 100,000 acres of the Tier 1 priority area. Within both these PNVTs, proposed treatments include either thinning by hand (using chain saws) or with the use of mechanical systems. The western portion of the Chino Valley Ranger District appears to contain the majority of the Tier 1 priority treatment areas. Figure 25 provides a more detailed view of this area (outlined in red).

Figure 25. Tier 1 Priority Treatment Areas Within the Chino Landscape Project



The southeast corner of the western section of the Chino Valley Ranger District appears to contain the highest concentration of Tier 1 PJ Evergreen Shrub PNVT. As such, TSS would expect that this would be one of the first areas accessed for PJ removal treatments. Considering the rather slow pace for completion of this plan, TSS does not expect much treatment activity until at 2020 or 2021.

Private Ranches

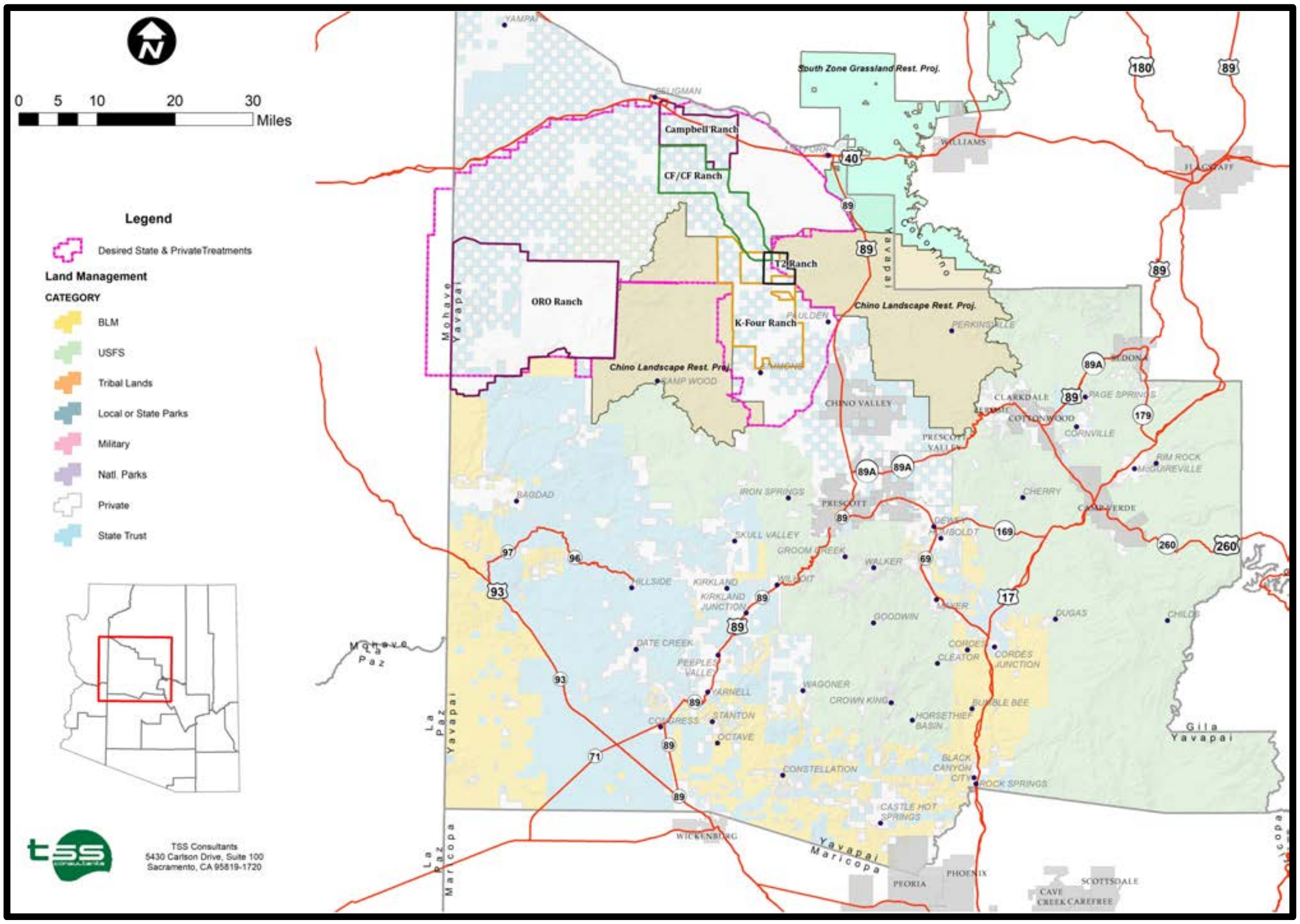
Within the TSA there are estimated to be almost 250,000 acres of PJ grasslands located on private land. The majority of this land consists of large ranches, some of which have been held by the same family for generations. The primary livelihood for these ranching operations is livestock production and as such, encroachment of PJ is considered a major detriment to forage production. Ranchers who spoke with TSS during this assessment were interested in removing PJ from their lands in order to facilitate grassland restoration (and higher forage production).

Many of the larger contiguous private ranch holdings and state grazing allotments are located within the Big Chino Valley and Williamson Valley in the TSA. Bordered by State Highway 89 on the east, County Road 5 on the west, and Interstate 40 on the north, this region contains some of the largest ranches in northern Arizona. Included in this area is the K4 Ranch containing approximately 54,000 acres, the Chino Grande Ranch[15] with approximately 50,000 acres and the Campbell Ranch with approximately 36,500 acres.[16] In addition, the smaller 7,800 acre T2 Ranch and the 5,200 acre Lobo Ranch are also within the TSA. The map in Figure 26 shows the general location of these ranches.

[15] Formerly the CV/CF Ranch.

[16] 15,000 acres south of I40 and an additional 21,500 acres north of I40, per the Central Arizona Grassland Conservation Strategy. Arizona Game and Fish Department, BLM, Prescott NF, Tonto NF. Resource Conservation Service. May 2014.

Figure 26. Private Ranch Holdings and Grazing Allotments Within the Study Area



During the course of this analysis, TSS met with Joe Campbell from the Campbell Ranch. Mr. Campbell indicated that he has been actively removing PJ from his ranch for many years. While Mr. Campbell appears to prefer grubbing out the entire root wad and then pile and burning, he is also open to participating in a PJ removal program using other mechanical methods such as shearing or mastication, assuming it can be done on a cost effective breakeven basis.

During this analysis it was determined that the K4 Ranch has been conducting ongoing PJ mastication operations. In 2017 it is estimated that the K4 Ranch masticated approximately 6,000 acres of PJ dominated acreage within the ranch. Matt Monahan, the mastication contractor on the K4 Ranch, indicated a willingness to consider shearing and removal of PJ biomass in the future if economical markets were to develop. Mr. Monahan believes that the K4 Ranch has another 8,000 acres currently available for treatment. With a satisfactory long-term market, he would be willing to invest in a shearing and grinding operation.

The Chino Grande Ranch consists of a number of smaller ranches that have been purchased over the years, including the CV and CF Ranches and the BMW Ranch.

Owners of the Chino Grande indicated that the ranch is in escrow and any future PJ treatment considerations will need to be taken up with the new owners.

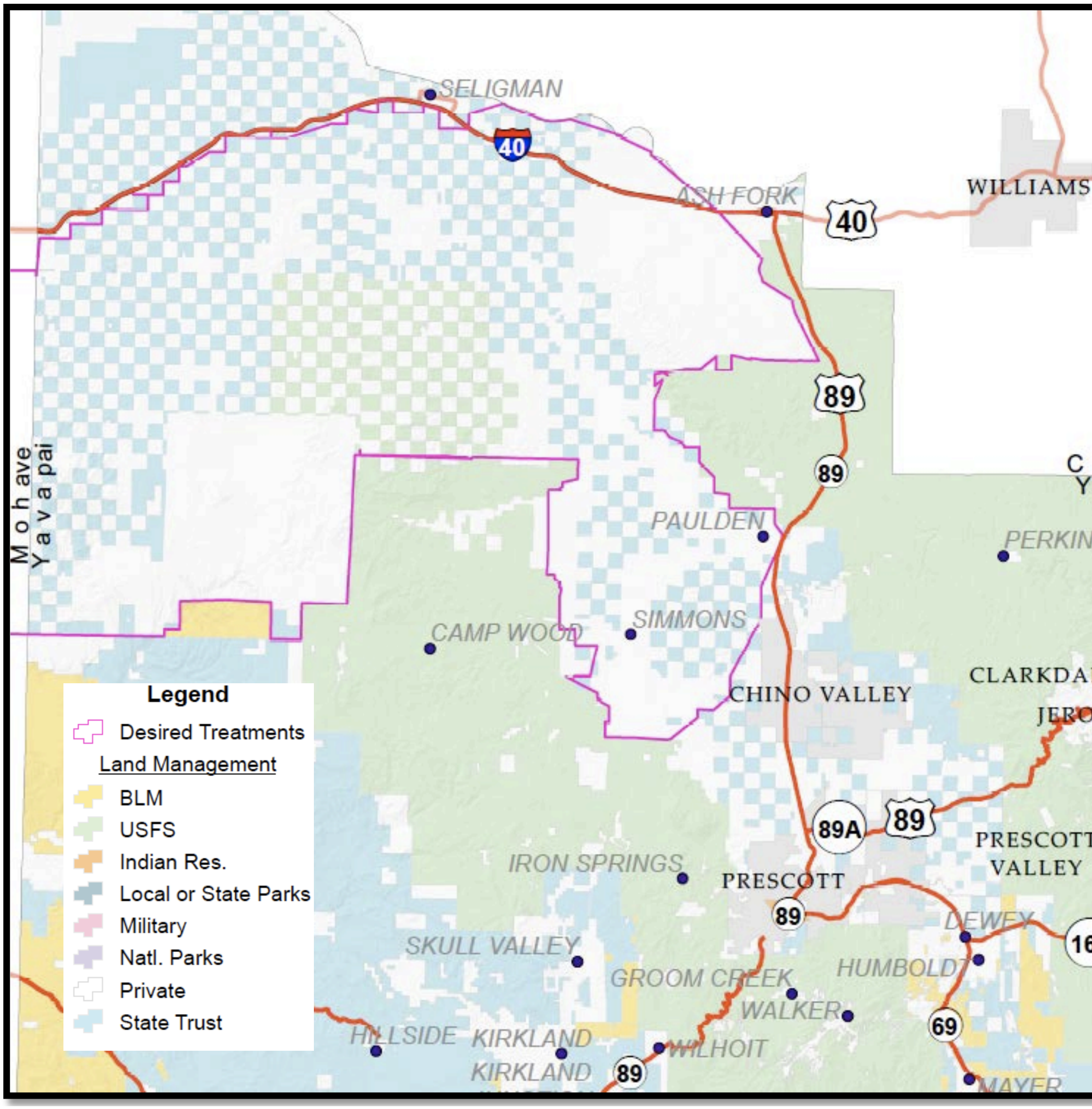
The largest ranch in the TSA is the ORO Ranch located further to the west of the above-mentioned ranches. According to Cory Pritchard (ranch manager), this ranch consists of approximately 257,000 acres. Over the past five years, the owners have been very active with a number of projects to reduce PJ encroachment on the property. Most recently, the ranch purchased mastication equipment to assist with eliminating PJ. Mr. Pritchard indicated that the ranch would be interested in investigating future mechanical treatment opportunities. Transportation distance from this location to possible biomass markets in and around the Chino Valley and Prescott area make this a lower priority opportunity. Figure 26 shows the location of the ORO Ranch.

Based on this analysis, the Campbell Ranch and K4 Ranch offer the most significant opportunity for implementation of PJ removal projects in the short term (next one to two years).

<u>State Lands</u>

Within the TSA there are almost 150,000 acres of PJ grasslands on State Trust lands. During discussions with Russ Shumate of the Arizona Department of Forestry and Fire Management, it was apparent that treatment of a large area of the Upper Verde River watershed is a priority for the department. Figure 27 highlights this estimated priority treatment area (boundaries shown in purple).

Figure 27. State Trust Lands Targeted for Priority Treatment



While this may in fact be a priority area for the State, TSS believes it to be a very ambitious project area. A key consideration regarding treatment and removal of woody biomass from State lands is the need for archeological site surveys. This process can be time consuming and costly. Archeological surveys are estimated to cost approximately $22 per acre within central Arizona. Assuming an average volume of approximately 7.5 BDT of PJ biomass per acre, archeological survey work alone on these lands could cost almost $3 per BDT.

Utilizing the State's Incidental Use Permit (IUP)[17] process, it is possible for an individual or enterprise to apply for the purchase and removal of PJ biomass from these lands. Once

[17] Personal communications with Chris Lowman, Range Resource Area Manager, Arizona State Land Department. January 2018.

the permit process is initiated, the State Land Department will complete a rough inventory of the material and generate a valuation appraisal. If the appraisal findings are negative or neutral, the State Land Department can sell directly to the applicant. If the appraisal findings result in a positive value, the product must be sold through a public auction. Follow-up efforts with the State Land Department should be undertaken in order to develop more focused priority areas within the TSA. Time and expense to conduct the IUP process and archeological survey work on State Trust Lands will require one to three years to complete.

All Ownerships Summary

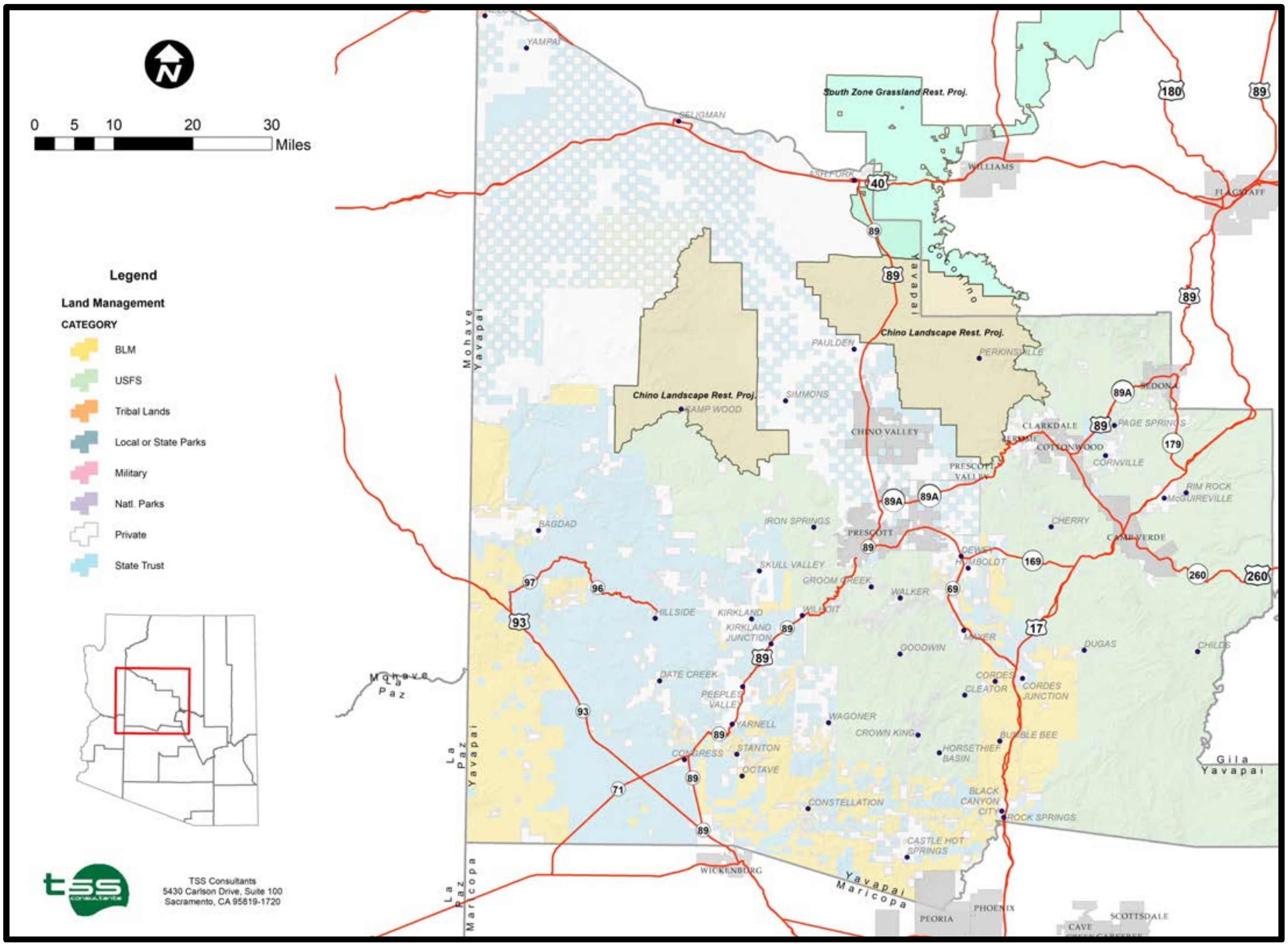
Based on this analysis, private lands offer the most immediate opportunities to access woody biomass from PJ treatments within the TSA. Most large ranch managers contacted during this analysis are currently conducting PJ treatments. As such, those areas indicated in Figure 26 on the Campbell Ranch and K4 Ranch appear to offer the most promising locations for commencement of mechanical treatment and removal of PJ material. Interspersed within these private ranch holdings are thousands of acres of State Trust lands, much of which are considered priority treatment areas. Efforts to operate and remove PJ on these State Trust lands should be conducted in conjunction with private land treatments. However, as previously stated, IUPs and archeological clearance must first be obtained prior to removal of this material. Time and expense for this effort will likely minimize PJ removal efforts on State Trust lands.

Following these private ranch holdings and State Trust lands, the areas covered by the South Zone Grassland Restoration Project on the Williams Ranger District of the Kaibab National Forest appear to offer the next most likely large-scale treatment project areas (specifically, the project area known as the Wash Tub Treatment area and identified in Figure 23). TSS estimates that over 5,000 acres of the Wash Tub Treatment Area is located within the TSA and could utilize mechanical treatment and removal of PJ biomass.

Finally, the Chino Landscape Restoration Project, while still in the planning stages, should provide for larger-scale PJ treatment projects specifically in the southeast corner of the western half of the Chino Valley Ranger District. Figure 25 shows the location of this Tier 1 priority treatment area. Considering the pace at which this project has been progressing, TSS believes this will not be ready for any actual project operations for at least three years.

Figure 28 provides an overview of strategic land ownerships that are interested in grasslands restoration projects that could generate significant volumes of PJ material.

Figure 28. PJ Grasslands Project Overview Map



Short term (12 months or less), the ranches (particularly the Campbell Ranch and K4 Ranch) offer the best prospects for significant volume of PJ removals. While no formal treatment schedule has been prepared by either ranch, TSS estimates that 8,000 to 10,000 acres could be readily available for treatment. In addition, adjacent State Trust lands could also be accessed during this time period; however, the time and economics of archeological clearance by the State will likely limit the amount of PJ available for removal.

Table 6 provides a summary of these potential treatment areas within the TSA.

Table 6. Summary of Potential PJ Treatment Areas by Ownership

Ownership	Total Acreage in Study Area	Potential Acreage Targeted for Treatment Per Year	Initial Implementation Target Years	Comments
Private Ranches	247,848	8,000 to 10,000	2018-2023	
US Forest Service	546,247	1,000 to 3,000	5,000 acres South Zone 2019-2020 247,000 acres Chino Landscape 2021	Includes PJ Grasslands in Chino Landscape and South Zone Restoration Projects
Arizona State Trust Lands	148,000	1,000	2019-2023	Dependent upon archeological survey efforts and IUP
Totals	942,095	10,000 to 13,000		

Potential Long-Term Feedstock Procurement

During the course of this analysis, TSS encountered several contractors in and around Yavapai County that indicated an interest in pursuing mechanical harvesting and processing of PJ. Clearly, a key driver to any such economic and operational decision would be the availability of a long-term biomass purchase agreement. There is currently no large-scale commercial market for woody biomass produced within the TSA.

In an effort to determine possible large-scale commercial markets, TSS met with Jade Navarro, Operations Manager for Gro-Well Brands in Phoenix. Ms. Navarro did express some interest in the prospects of utilizing chipped PJ material in a landscape mulch product. However, she also indicated that an acceptable product could only have about 10% foliage and other contaminants making it extremely difficult to produce a processed PJ product that would meet the Gro-Well specifications.

In addition, TSS has discussed the potential for utilizing processed PJ material as a feedstock in residential wood pellet production. Based on discussions with commercial pellet manufacturers,[18] PJ wood fiber and sawdust contains elevated levels of silica, which is very abrasive and produces accelerated wear in the pellet processing equipment.[19] TSS is unaware of any commercial-scale fuel pellet production facility

[18] Personal communications with Curtis Rogers, Forest Energy Corp, Show Low AZ, and Jeff Raines, CEO, Pacific Pellets, Redmond OR.
[19] Primarily wood pellet dies.

utilizing PJ feedstock and it is unlikely that PJ material will serve as a cost effective feedstock for pellet production.

Feedstock Pricing

Discussions with contractors currently conducting PJ treatments within the TSA indicated that private landowners (primarily ranchers) are willing to provide only minimal compensation in the form of service fees ($/acre) for PJ removal or mastication to support grassland restoration activities. In one case, a mastication contractor indicated that $40/acre was the typical service fee paid by private landowners. Other landowners suggested a breakeven scenario, whereby the landowner would shear the trees and allow removal of the PJ stems at no cost. Existing operations now harvesting PJ material report being paid $38/BDT for processed PJ material delivered within about 30-mile one-way transport distance, with little if any service fee provided by the landowner.

Based on this limited sample size, for any long-term PJ removal contract, the landowners will only consider a minimal service fee ($0 to $40 per acre). While the National Resources Conservation Service (NRCS) does provide funding to private landowners for PJ treatment and grassland restoration, budget constraints limit the treatment acreage to approximately 1,000 acres per year in Yavapai County.[20]

Stewardship Contracts

While the South Zone Restoration Project has been completed on the Williams Ranger District of the Kaibab National Forest, TSS learned that there are no immediate plans to pursue PJ treatment contracts at this time. The Kaibab Nation Forest's primary focus is to prep and administrate the 4FRI project. At this time, there are no plans by the US Forest Service to implement stewardship contracts (typically three to ten year duration) within the TSA.

Agreements with Ranches

As previously discussed, private ranchers appear to be the most likely candidates to initiate any significant PJ removals in the short-term (one to two years). Currently, most private ranches appear to be paying minimal service fees for PJ treatment. TSS estimates that any long-term contract with ranchers would result in service fees ranging from $0 to $40 per acre.

Incentives Available to Offset Grassland Restoration Costs

Several programs have been used to help offset the cost of PJ grassland restoration efforts. The NRCS program provides funds directly to landowners as part of the Environmental Quality Improvement Program (EQIP). Payments average about $185 per acre. However, the budget for this program is limited and it is estimated that only about 1,000 acres will be available for funding this fiscal year (2018). Other programs include

[20] Personal communications with Marques Munis, Rangeland Management Specialist, NRCS, Prescott Valley Field Office.

wildlife habitat improvement funding from the Arizona Department of Game and Fish as well as various wildlife foundations.

Summarized below is a list of key initiatives and incentives that would facilitate expansion of PJ biomass feedstock supply.

- Long-term sustained funding levels for NRCS EQIP targeting grassland and watershed restoration.
- Concerted efforts by the USFS to initiate grassland restoration activities within the TSA.
- Arizona State Land Department embarking on a pilot project to proactively restore grasslands, thus enhancing the Department's ability to issue grazing allotments and thereby allowing highest and best use (in addition, maximizing net revenue back to the State).
- Long-term commitment by the Arizona Department of Transportation to support the Healthy Forest Initiative.
- Consider state-sponsored biomass producer tax credits (similar to those used in Oregon) to offset the cost of processing and transporting biomass material.
- Consider a public benefits charge on residential ratepayer's water consumption bills to fund upland watershed restoration.

Next Steps to Consider to Support Supply Chain Expansion

The most critical step is to develop an active commercial market for utilization of PJ biomass material. It was recently announced by Salt River Project that they will be requesting proposals for renewable energy projects in 2018. Appendix B is the SRP announcement. In addition, Arizona Public Service has issued a bioenergy request for proposals (see Appendix C for the announcement). While it remains to be seen if biomass power generation can be competitive in the current renewable energy marketplace, this is a very important step for a potential large-scale biomass market within or adjacent to the TSA.

Summarized below is a list of next steps to consider in support of PJ feedstock supply chain development.

- Consider teaming with like-minded entities (The Nature Conservancy, Rocky Mountain Elk Foundation, Wild Turkey Foundation) to facilitate discussions with the USFS and Arizona State Lands Department to initiate landscape-scale grassland restoration and watershed improvement activities within Yavapai County.
- Conduct outreach to the Arizona Corporation Commission to stress the opportunity to not only treat excess biomass on forestland, but also treat key watersheds currently dominated by PJ vegetation. Adding woody biomass renewable power generation to the Renewable Energy Standard could facilitate commercial markets for PJ material.
- Conduct PJ feedstock trials with commercial-scale mulch and soil amendment enterprises (e.g., Gro-Well, Scotts) to assess potential markets for PJ material.

Feedstock Competition Analysis

Demand for woody biomass and other forest products within Yavapai County is currently limited to fuelwood use and a limited number of timber sales. However, local leadership provided by the Coalition and the desire of a variety of stakeholders, including landowners and land managers, indicates community support to manage vegetation density to reduce wildfire risk and improve water supply security. During the course of this analysis, TSS observed processed green waste at the City of Prescott transfer station being loaded on a walking floor trailer for transport to Scotts Miracle Gro, 139 miles south in Maricopa. The City of Prescott provides this material free, and Scotts pays the transportation cost.

<u>Current Competition</u>

Current market demand for woody biomass within the TSA is limited to fuelwood and some green waste. As mentioned above, the City of Prescott transfer station provides processed green waste for free (typically for use as mulch). Perhaps the most significant competition for Yavapai County biomass are the forest residues generated from the 4FRI stewardship contract located to the north and east of the TSA. During this investigation, TSS was informed that thousands of tons of chipped and ground pine timber harvest residues must be removed from the 4FRI harvest units. This material is generally easier to process than pinyon and juniper and has much less foliage; as such, it will likely be difficult for PJ biomass to compete in the current woody biomass marketplace.

<u>Potential Market Risks</u>

The biggest risk to future supply is the current lack of viable markets for woody biomass. Without a large-scale industrial user within close proximity of the resource, it will be very difficult to develop a PJ biomass supply program within the TSA. There are a number of new and innovative technologies under various stages of development that utilize PJ biomass as a feedstock. Considering the fact that the 4FRI stewardship project has had an ongoing effort trying to identify and develop markets for the thousands of tons of pine chips that are being developed off this project, PJ biomass may be a low priority feedstock consideration for most of these technologies. Another risk consideration is the slow growth rates for juniper and pinyon-juniper woodlands. Most large-scale commercial users of biomass consider a 30-year project life span as critical to economic success. Slow regeneration rates for juniper on most of the TSA will limit the economical removal to a single harvest per acre over a 30-year project life cycle. However, once a supply stream for this feedstock is developed, the PJ source may be a viable niche for the right business. Notable possible advantages for marketing material in this TSA is its relative proximity to a railroad shipping center and its close proximity to markets in California.

<u>Emerging Pinyon-Juniper Utilization</u>

Utilization of PJ residuals resulting from grasslands restoration is an active area of research by stakeholders, universities and private industry. Utilization ranges from small-scale, low technology uses such as on-site erosion control ‘Juniper Silt Dams’ to large-scale high technology uses such as bioenergy facilities. Examples of value-added utilization processes and products are shown in Table 7.

The TSA has an existing well-developed firewood market, but there could be potential for other densified fuel products, such as fuel bricks. In New Mexico, PJ Woodlands, LLC, has co-developed with the USFS Forest Products Lab a durable wood fiber composite called Altree that is made from PJ biomass feedstock. It is currently used to manufacture road signs for USFS lands.[21, 22] The use of juniper and pinyon for essential oils is an emerging market.[23] Oils are bottled and used in aromatherapy and personal care products (example businesses include Young Living Farms and Floracopiea).[24] Landscape products are a well-established use of wood chips, and at least one business in the TSA is interested in juniper as a decay resistant and insect repellant mulch product.[25]

---

[21] Altree Industrial Grade Composites, made by PJ Woodlands, Albuquerque, NM: http://www.altree.com/
[22] Altree wood chip and plastic panel substitute finds use in road signs. Woodworking Network. May, 2016. http://www.woodworkingnetwork.com/wood/panel-supply/altree-wood-panel-substitute
[23] USU Forestry Extension Volume 20, Number 1, 2016: http://forestry.usu.edu/files/uploads/UFNSpring2016Final.pdf#page=5:
[24] Young Living Essential Oils: https://www.youngliving.com/en_US/discover; Floracopiea: http://www.floracopeia.com/about/sangre-de-cristo-project/
[25] Scotts Miracle Gro, personal communication, May, 2016.

Table 7. PJ Utilization Examples

Process or Product	Feedstock Specifications	Primary Equipment	Market Potential and Comments
Wood Fuel Pellets	Clean, dry (<10% mc) chip, needs to be <1% ash.	Pellet mill, dryer, cooler, hammermill (grinder or chipper), packaging.	Market is domestic stoves and larger-scale biomass boilers. Can be co-fired with coal. Could seek access to international markets. Locally, Drake Cement is an example of co-firing with biomass. Use of either roundwood or biomass from forest possible (e.g., small logs or chips low in bark). Key issue and expense is drying system. Larger-scale facility may face challenges in gaining market share for domestic stoves from existing competition. International energy markets for co-firing with coal depend on transport costs and currency fluctuations. Discussions with existing fuel pellet processor confirm there may be issues utilizing PJ as primary feedstock, due to high silica content.
Compressed Wood Fuel Bricks	Chip, dry (<15% mc), needles, bark okay.	Brick machine, dryer, cooler, hammermill (grinder or chipper), packaging. May also be field dried and no dryer needed.	Primary market is substitute for firewood. Also used for camping, lighter and more portable. Small scale can sell by pallet or truckload. Larger-scale operations may need packaging equipment. Utilizes PJ residuals including needles and bark. Potential to use field-dried material as feedstock with no kiln drying. Smaller mobile units can follow woodcutters or restoration operations and utilize residual piled slash.
Plastic/Wood Fiber Composites (WPC)	Clean, dry (2-12% mc) wood flour. Wood is ~55% of feedstock along with plastic and additives. Recycled wood use common.	Blender (compounder extruder), extrusion line, cooler, cut-off saw.	Composite woods are used for landscape (bender board), decking, fencing, park furniture (picnic tables and seats). The composite wood furniture market is growing due to interest in sustainability. Increasingly used in buildings, exterior siding. Requires cost effective thermoplastic feedstock (HDPE, LDPE, PP, PVC). Utilize recycled plastics (milk jugs, plastic bags). Commercial facilities typically use pine, oak and maple. Blending (compounding) of wood and plastic may be two processes or single process depending upon equipment.
Compound Pellets for WPC Production	Same as above.	Compounder extruder.	Existing wood plastic composite pellet mills. WPC pellets can be used as the raw material for production of decking material, outdoor furniture and landscape (bender board). Cheaper way to get into WPC marketplace than making finished products.
Essential Oils	Clean juniper or pinyon chip. Debarked.	Steam distillation. Oil extraction by a cold press technique.	Niche use for juniper, which has an oily, aromatic extract. There are also some pinyon essential oils. Little or no data yet (not well-studied) on capital costs and revenues. Marketing is both by internet sales and in specialty shops.

Feedstock Cost Forecast

With virtually no existing markets for woody biomass within the TSA, and very limited removal operations, the cost of harvest, collection, processing and transport is hard to determine. During this review, TSS learned that clean pine wood chips are in demand at Scotts Miracle Gro and Gro-Well in the Phoenix area. Also, Novo BioPower in Snowflake, Arizona has been purchasing some pine biomass fuel. As stated earlier, the City of Prescott is currently giving away processed green waste from their transfer station.

Current Market Prices

Markets are limited for woody biomass in the TSA and nonexistent for PJ biomass except as fuel wood. TSS did find that mulch material made from conifer chips from the 4FRI project is selling for about $1,150 per load to Gro-Well, or about $47 to $50 per green ton (GT) delivered. This market appears fairly robust, with one 4FRI operator indicating that this past winter they shipped 40 loads per day into Gro-Well. However, the seasonality of these mulch and landscape markets can create boom and bust market cycles. It is unclear how much material these two users might purchase over an entire year. Additionally, TSS was informed that these buyers seek clean conifer chip material, and there is some concern that it will be difficult to meet the feedstock specifications with PJ material. Scotts is willing to try a test load of chipped PJ material to determine if it would be feasible to use in their mulch process. TSS also contacted Novo BioPower in Snowflake, Arizona. This 27 MW biomass power plant does burn PJ biomass fuel and currently pays $36 to $38 per delivered bone dry ton.[26] Considering the fact that this facility is 211 miles (one-way haul distance) from Prescott, it would not appear to be a viable market for Yavapai County due to excessive transport costs.[27]

Delivered Cost Forecast

With no current markets for PJ biomass, it is difficult to make any kind of projection as to where delivered prices might go. Based on cost data developed from the 2012 PJ study,[28] ARRA Study, and the 2016 Savannah-Grasslands Pre-Investment Pilot Project[29] as well as anecdotal information from other producers, TSS estimates that the cost for PJ biomass harvested, collected and processed into a chip truck will be in the range of $45 to $65 per BDT. Assuming an average one-way haul distance of 40 miles equates to around $10 per BDT, the total delivered cost for PJ biomass would be $55 to $75 per BDT.

As discussed earlier, the Drake Cement operation could be a potential market. Potential demand of up to 65,000 GT per year has been reported.[30] A key consideration for Drake Cement would be the cost to replace the coal currently used in their kiln. TSS estimates

[26] One bone dry ton = 2,000 pounds of dry wood fiber.
[27] Likely a nine hour round trip with cost estimated at $50 to $60/BDT.
[28] ARRA Grant Project #AR 10-001, USFS Recovery Act Agreement #10-DG-11039702-109, April 2012.
[29] Savannah-Grasslands Pre-Investment Pilot Project, Southwest Forestry Inc., DR Systems NW, Inc., June 2016.
[30] Completed Project Report: Drake Biomass Development Project Results and Applications, Arizona State Forestry Division, Nov. 2012.

that Drake pays around \$3.20/MMbtu[31] for coal, and assuming pinyon and juniper biomass to be around 16.8 MMbtu per BDT,[32] this equates to approximately \$3.87/MMBtu (assuming \$65 per delivered BDT for pinyon and juniper biomass). At this time, Drake Cement does not appear to be a ready market for PJ biomass material.

Table 8 summarizes biomass feedstock costs on a delivered basis assuming a 40-mile one-way haul distance.

Table 8. Delivered Feedstock Cost Forecast 2017 through 2021

	Delivered Prices Base Case		Delivered Prices Worst Case	
Feedstock Type	**Low Range (\$/BDT)**	**High Range (\$/BDT)**	**Low Range (\$/BDT)**	**High Range (\$/BDT)**
Timber Harvest Residuals	\$45	\$50	\$50	\$55
Forest Management and Restoration	\$45	\$50	\$50	\$55
Juniper and Pinyon-Juniper Treatment	\$55	\$75	\$60	\$85

Base case cost forecast assumes forest density conditions at the mid to high-density removal levels (5 to 15 BDT/acre) which are typically lower cost. Worst case forecast assumes relatively low forest density conditions (3 to 5 BDT/acre) for removal, resulting in higher costs to collect and process material.

When considering biomass fuel cost forecasts, it is important to understand that the largest single variable affecting the cost of this material is the price of diesel fuel. At approximately 4 gallons of diesel to harvest, collect, process, and transport a BDT of woody biomass, it is easy to see how diesel fuel pricing can impact delivered biomass fuel costs. For the next five years, TSS is projecting relatively flat diesel fuel prices and therefore a relatively flat price increase of 1.5% per year.

---

31 MMBtu is one million British thermal units, a measure of heating value.

32 Based on 8,400 Btu/dry pound for high heat value from a recent study.

Findings

<u>Planned Projects</u>

TSS found that the Prescott National Forest, Chino Ranger District, is preparing the Chino Restoration Project. This is a two-tiered project covering approximately 430,000 acres. The Tier 1 portion of the plan is expected to treat approximately 90,000 acres and includes PJ grasslands restoration. Recently the Kaibab National Forest finalized the 550,000-acre South Zone Restoration project; some 270,000 acres of the project are on the Williams Ranger District. While only a small part of this project acreage is actually located within the TSA, there is some PJ biomass removal anticipated within this project. In terms of large-scale PJ treatments, it was found that the Kaibab National Forest, Williams Ranger District, has been the most active over the past decade. This district has treated thousands of acres of PJ vegetation type and helped to develop some of the mechanical treatment methods that are prominent in the region today.

While neither of these projects were able to shed much light on the potential biomass volumes across these large project landscapes, TSS believes over the long term, the NEPA and EA documents will be critical for opening up large acreages of PJ vegetation type on USFS managed lands, to future treatments. The NEPA and EA analysis process can require 24 to 36 months to reach a Record of Decision, so lead time planning is critical.

Attempts to increase the pace and scale of forest and grassland treatments will require significant investment of time and resources on the part of the major land manager in the region, the USFS. This agency manages over 56% of the PJ grasslands and over 76% of the conifer forests within the TSA. If improved value-added markets can be developed and federal funding appropriated, there is significant opportunity to ramp up the pace and scale of treatment of both forest and grassland landscapes within the TSA.

<u>Biomass Feedstock Supply Availability</u>

The predominant vegetation types of interest within the study area are the juniper and pinyon-juniper grasslands. This vegetation type represents over 960,000 acres or approximately 18.5% of the TSA. While conifer forest types do exist within the TSA, they are of minor relative importance, making up about 2% of the area. Although the PJ grasslands are abundant within the TSA, TSS found limited data regarding potential aboveground biomass volume for this vegetation type within the TSA. Utilizing a wide range of aboveground biomass estimates for PJ stands within Arizona and the Southwest U.S., TSS estimated a range of 4.7 BDT/acre to 10.6 BDT/acre, averaging around 7.65 BDT/acre. TSS estimates that 2,500 to 3,300 acres of juniper and pinyon-juniper grasslands are treated annually within the TSA; however, little if any of this material is currently utilized (most is masticated on site). In terms of other forms of biomass potentially available, such as conifer forest and urban-derived material, TSS found these to be around 10,000 BDT per year. Obviously, the current and future biomass opportunities within the TSA are with the PJ grasslands.

Feedstock Competition Analysis

Markets for processed woody biomass are virtually non-existent within the TSA. TSS observed green waste mulch being processed for transport 139 miles south to Scotts Miracle-Gro in Maricopa, at no cost to Scotts. In addition, discussions with timber operators and truckers in the region indicated that the only markets for processed woody biomass generated from USFS timber harvest residues are either Scotts in Maricopa, Gro-Well in Phoenix, or Novo BioPower, a 27 megawatt (MW) biomass power plant located in Snowflake. TSS estimates that haul distances to these markets range from 211 miles (Novo BioPower) to 125 miles (Gro-Well) from Prescott.

While the primary focus of this project was to assess the potential volumes of biomass that could be available for commercial use within the TSA, TSS did take a cursory look at some markets and associated competition from other biomass outside the immediate study area. One of the major competitive forces impacting the potential for developing markets for the PJ biomass resource within the TSA is the 4FRI project. The 4FRI is the largest USFS stewardship contract in the agency's history and is located along the northern and eastern border of Yavapai County. This massive, 10-year, 300,000 acre project is producing sawlogs, posts, poles and thousands of tons of woody biomass. TSS believes that much of the woody biomass generated from the 4FRI will be in direct market competition to any woody biomass generated in Yavapai County. TSS found that woody biomass produced by contractors on the 4FRI project is being hauled to some of the same mulch and landscape market outlets that TSS contacted as part of this assessment. Much of the biomass from the 4FRI project consists of high-quality chipped pine and is being transported directly through Yavapai County to Scotts Miracle-Gro and Gro-Well. The fact that the 4FRI contract requires removal of all woody biomass from the contract area suggests that these woody biomass producers will be extremely price competitive.

Based on discussions with the largest wood pellet manufacturer in Arizona, TSS found that juniper is not a desirable feedstock for residential fuel pellet production. The abrasive characteristics of juniper cause excessive wear of the pellet dies. This manufacturer also indicated that delivered prices for PJ woody biomass were not competitive with pine and conifer woody biomass.

Feedstock Cost Forecast

TSS is aware of only one wood grinder operating within the TSA, a Vermeer horizontal grinder that is owned by Yavapai County. This machine is currently used by Yavapai County at the City of Prescott transfer station. With such a limited number of actual wood processors in the TSA, it was necessary for TSS to rely on the recent PJ grasslands research projects as well as anecdotal information from operators in other regions of the Southwest. Based on this information, TSS estimates that PJ material could be processed and delivered within a 40 mile one-way haul distance for $55 to $75 per BDT. Timber harvest residues and forest management material were estimated at $45 to $50 per delivered BDT.

In terms of biomass fuel forecast, the largest single expense related to biomass fuel harvesting and processing is the cost of diesel fuel. Over the next five years, TSS expects diesel fuel prices to remain flat. As such, TSS is projecting just a minimal 1.5% per year increase in these biomass feedstock costs.

Recommendations

Based on this feedstock supply assessment, TSS believes that any significant volume of woody biomass within the TSA will come from the PJ grasslands. Yavapai County and the Prescott National Forest are not traditional conifer forest products producing areas. With the onset of the 4FRI stewardship project, TSS believes that any commercial demand for conifer-derived biomass would likely locate to the north and east of Yavapai County, closer to the 4FRI project area. In consideration of these facts, TSS recommends that future efforts at quantifying biomass focus solely on the PJ resource. Much has been researched and written about the juniper and pinyon-juniper grasslands of Yavapai County over the past six years. However, clear juniper and pinyon-juniper inventory data is still missing. During this review, TSS did attempt to pull together a significant amount of data related to pinyon-juniper aboveground biomass within the TSA. As was pointed out by one US Forest Service employee, however, "it is lots of work to quantify the volume" of these grasslands. Yavapai County is certainly not alone in this pinyon-juniper inventory dilemma; many jurisdictions across the southwest United States are faced with a similar issue, and it is not new. Attempts at devising age class and volume tables can be challenging. PJ often grows inconsistently, physical characteristics vary based on site conditions, and it can be difficult to assess tree age.

Recent research conducted by the USDA Agricultural Research Service may help to develop better estimates for aboveground biomass of PJ grasslands. Utilizing object-based image analysis (OBIA) techniques and National Agricultural Imagery Program (NAIP) imagery in combination with ground measurements, researchers were able to develop a method to provide land managers with quantitative data that can be used to evaluate PJ grassland cover and aboveground biomass rapidly over a broad landscape.[33] TSS recommends that any further investigation into the availability of PJ grassland biomass within the Upper Verde River watershed and Yavapai County consider incorporating this remote-sensing methodology to better describe the aboveground biomass within this TSA.

---

[33] Utilizing National Agriculture Imagery Program Data to Estimate Tree Cover and Biomass of Pinon and Juniper Woodlands. April Hulet et al, Rangeland Ecology & Management 67(5): 563-572: 2014.

VALUE-ADDED CONVERSION TECHNOLOGY REVIEW

TSS examined numerous value-added biomass conversion technologies that could potentially utilize the excess woody biomass determined to be sustainably available within the TSA. Biomass conversion technologies listed below were examined with results presented in a tabular matrix format. Utilizing the Coalition project team input, a selection of preferred conversion technology(s) was made and is presented below.

Conversion Technologies to be Considered

The following biomass conversion technologies are being considered by the Coalition for potential manufacture of biomass-based products for use in Yavapai County, or for export out of the region.

- Industrial-grade fuel pellets
- Torrefied fuels
- Bio-coal (Enginuity Process)
- Biochar and activated carbon
- Fuel bricks
- Storm water wattles with wood chips and biochar

Findings from the October 2016 biomass feedstock supply availability assessment indicated the following:

- Approximately 25,000 BDT/year of wood waste economically available.
- This volume could expand to over 100,000 BDT/year if local biomass markets existed.
- Average cost of delivered feedstock would be approximately $65/BDT.[34]
- Delivered feedstock would be in the 15 to 25% moisture content range.

Conversion technologies were examined, discussed, and reviewed in the context of utilizing the feedstock summarized above.

Industrial-Grade Fuel Pellets

Pellet fuels (or pellets) are biofuels made from compressed organic matter typically made up of woody biomass. Pellets can be made from any one of five general categories of biomass: industrial waste (typically from wood processing facilities) and co-products, food waste, agricultural residues, energy crops, and excess biomass from fuels reduction operations. Wood pellets are the most common type of pellet fuel and are generally made from compacted sawdust and related industrial wastes from the milling of lumber, manufacture of wood products and furniture, and construction. Other biomass wastes to make pellets include slash from forest thinning and timber harvesting. So-called "black pellets" are made of biomass,

[34] This cost assumes in the first 10 years there would be a focus on operating in the mid to high-density stands of pinyon pine and juniper.

refined to resemble hard coal, and were developed to be used in existing coal-fired power plants. Pellets are categorized by heating value, moisture and ash content, and dimensions. They can be used as fuels for power generation, commercial or residential heating, and cooking. Pellets are extremely dense and can be produced with a low moisture content (below 10%) that allows them to be burned with very high combustion efficiency. Further, their regular geometry and small size allow automatic feeding with very fine calibration. They can be fed to a burner by auger or by pneumatic conveying. Their high density also permits compact storage and transport over long distance. They can be conveniently blown from a tanker to a storage bunker or silo on a customer's premises.

Pellets are produced by compressing the wood material, which has first passed through a hammer mill to provide a uniform size and mass. This mass is fed to a press, where it is squeezed through a die having holes of the size required (normally 6 mm diameter, sometimes 8 mm or larger). The high pressure of the press causes the temperature of the wood to increase greatly, and the lignin plasticizes slightly, forming a natural "glue" that holds the pellet together as it cools.

A report by Consortium On Research on Renewable Industrial Material (CORRIM) for the Life-Cycle Inventory of Wood Pellet Manufacturing and Utilization estimates the energy required to dry, pelletize and transport is less than 11% of the energy content of the pellets if using pre-dried industrial wood waste. If the pellets are made directly from forest material, it takes up to 18% of the energy to dry the wood and additional 8% for transportation and manufacturing energy.

Wood pellet production in the United States and Canada is prodigious, with 200 pellet plants reported by Biomass Magazine as of May 2017.[35] Production capacity is also reported and is in excess of 17.5 MM Metric tons/year. A majority of these pellets are exported to Europe and Asia for electricity production (to offset coal combustion) by very large facilities concentrated in the Southeastern United States, British Columbia, and Ontario.

Representative vendors

Forest Energy Corporation – Show Low, AZ
http://forestenergy.com

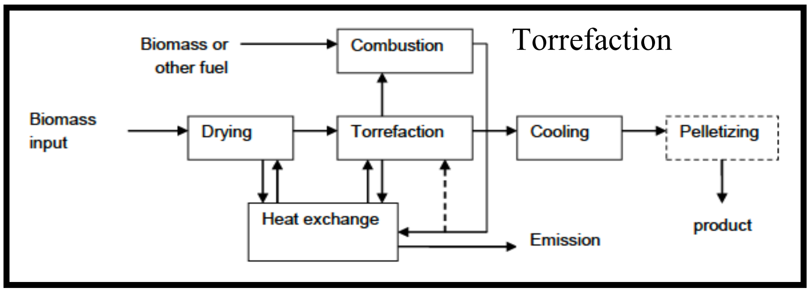
Confluence Energy – Kremmling, CO
http://www.confluenceenergy.com

[35] See: http://biomassmagazine.com/plants/listplants/pellet/US/

Torrefied fuels

Torrefied fuels are typically produced using low temperature pyrolysis of woody biomass waste so as to increase the quality of the feedstock as a 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 (also known as bio-coal) is low-temperature (approximately 400 to 600°F) pyrolysis that is used to remove water and volatile material from 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).



The primary marketable product is torrefied wood in its original form. Torrefied wood can be processed into a briquette or pellet. It 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 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 is 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 greenhouse gas 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 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 the switch 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, the market prices for coal and natural gas are approximately $2.20/MMBtu and $3.41/MMBtu, respectively.[36] A recent study of torrefaction economics indicates that torrefied biomass was in the $6.90/MMBtu to $7.84/MMBtu range.[37]

<u>Conventional Woody Biomass v. Torrefied Biomass</u>

Presented below are the advantages of torrefied biomass over conventional woody biomass.

Conventional Woody Biomass

- Low calorific value, potentially high moisture content
- Low energy density
  - too bulky, not economical to transport over long distances
- Non-homogeneous
  - Wide variations in combustion properties (fixed C, VOCs, inorganic constituents, moisture, calorific value)
  - Wide variations in sizes, shapes and types (handling and storage difficulties)
- Low combustion efficiency, smoking during combustion
- Difficult to pulverize like coal (poor grindability)
- Hygroscopic (absorbs moisture during storage)
- Significant inorganic matter content (mainly Ca, Si and K)
  - ash-related problems (sintering, fusion, agglomeration)
  - coal generally has a much higher ash content, but biomass ash is more prone to slagging & fouling

[36] U.S. Energy Information Agency, March 2018. https://www.eia.gov/outlooks/steo/tables/pdf/2tab.pdf
[37] "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

Torrefied Biomass

- Improves the physical characteristics of biomass, and thus the overall economics of the biomass utilization process for energy production.
- Torrefied product is a homogeneous solid fuel with:
  - Higher energy content (per unit volume) and
  - Lower moisture content
- Makes biomass friable
  - 80-90% less energy consumption for grinding
- Makes biomass hydrophobic
  - Transport and material handling is less expensive & easier
  - Outdoor storage possible - less expensive storage option
  - Significant loss of energy due to re-absorption of moisture in biomass (pellets) is saved
- Negligible biological activities (decomposition, mold)
  - Longer storage life without fuel degradation
- Low Oxygen/Carbon ratio
  - Higher yield during gasification
- Smoke producing compounds removed
- Homogeneous output from mixed biomass
  - Torrefied biomass – more homogenous physical and chemical properties
  - Allows sourcing of different types of woody biomass for pelletizing in a single device – improves economics of pelletization
  - Possibility of utilizing different types of local woody biomass for energy use in a single combustion unit – improves fuel availability, supply reliability, and can reduce fuel cost
  - Makes pelletization easier – lignin fraction increases (by 10 to 15%)
  - Torrefied pellets have more strength – 1.5 to 2 times impact load, does not disintegrate easily during handling and storage

Representative Torrefaction Vendors

Agri-Tech Producers – Columbia, SC
http://www.agri-techproducers.com/default.html

River Basin Energy – Highlands Ranch, CO
http://www.riverbasinenergy.com

HM^3 Energy – Gresham, OR
http://hm3energy.com

Vega Biofuels – Norcross, GA
http://vegabiofuels.com

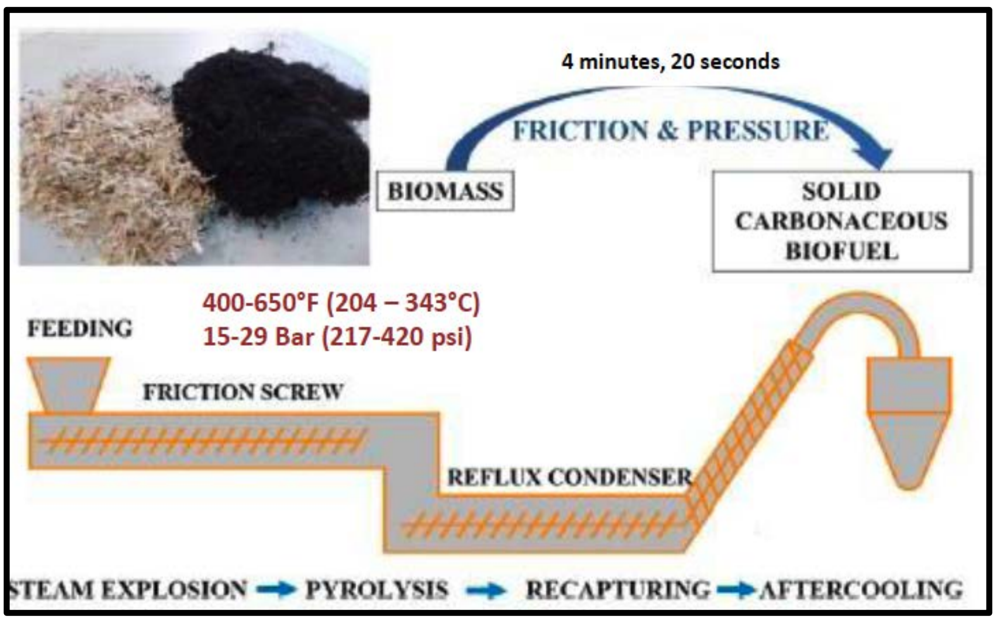
Active Energy Group, Advanced Biomass Solutions – London, UK
https://www.aegplc.com/advanced-biomass-solutions

Testing CoalSwitch™ at the University of Utah – Salt Lake City, UT
http://www.aegplc.com/advanced-biomass-solutions

Bio-coal (Enginuity Process)

Enginuity Worldwide, a team member of this Coalition supported research effort, is the developer of a novel method to produce bio-coal from woody biomass. Their process, known as Compression Frictional Treatment (CFT), emulates other biomass conversion processes such as drying, pyrolysis, and gasification. However, unlike conventional torrefaction, the Enginuity process utilizes only friction and compression, requires no external heat source, and occurs in their patented Rotary Compression Unit (RCU) as shown in Figure 30.

Figure 29. Enginuity Compression Friction Treatment Process



The RCU represents a novel approach to creating a bio-coal product by not requiring any external heat or steam source to convert biomass material, only energy to power a motor. It uses both friction and compression, generating steam from both unbound and bound water in the woody biomass. The overall CFT process converts biomass feedstock into engineered and upgraded bio-coal product with high heating value and energy density, almost the same as the heating value and density of fossil coal (approximately 11,000 Btu/pound). This bio-coal is thus engineered to fit the needs of a coal-fired power plant and be an effective alternative to coal that requires no changes in handling or combustion procedures or equipment.

The CFT process recovers more than 80% of the initial mass yield and 96% of the energy compared to the conventional torrefaction process that typically has 70% recovered yield and 91% of the energy. In addition, it has higher fixed carbon content with 28.3% versus 22.4 % for torrefaction.[38]

Biochar and Activated Carbon

Biochar is a thermally altered form of carbon that is a 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 waste is heated in the absence of oxygen to temperatures generally between approximately 600 to 1,300 degrees Fahrenheit. 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.

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

- Removal of contaminants from supply water, wastewater, and storm water;
- Replacement of perlite and peat in horticultural potting media;
- 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;
- Soil and mining wastes remediation;
- Incorporation as a soil amendment to increase water and nutrient retention in poor and degraded soils.

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

[38] "Introduction to Frictional Carbonization (FC) – An Alternative Method of Charcoal Production from Biomass." http://www.enginuityww.com/white_papers/introduction-to-frictional-carbonization-fc/

treatment plants is one of the more promising emerging applications. Considerable research is underway in this sector.[39]

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 production

Biochar is similar to activated carbon (AC) in many ways, with research conducted recently at Oregon State University showing great sorption of heavy metals by biochar. One significant difference between biochar and AC is price. AC can be in excess of $3,000 per ton 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 utilization 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 per pound and in bulk for $250 to $2,000 per ton, indicating that the biochar market is still trying to find a more stable price point. Previous interviews with biochar processors[40] 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 activated carbon sector, suggest that there could be higher market prices for the biochar product line in the near future.

Representative Biochar Vendors

Bioforcetech – Redwood City, CA
http://bioforcetech.com/index.html

BioEnergy Design – Paso Robles, CA
http://www.bioenergydesign.com/Home_Page.html

Biochar Solutions – Carbondale, CO
http://www.biocharsolutions.com

Pacific Biochar – Santa Rosa, CA
https://pacificbiochar.com

---

[39] 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.
[40] Greg Shipley, BioEnergy Design, and Greg Stangl, Phoenix Energy.

Fuel Bricks

Wood fuel bricks can be considered a potential added value utilization opportunity using biomass waste material sourced from hazardous fuels reduction, timber harvest operations, forest restoration and landfill wood waste recovery activities. A woody biomass briquetter, such as those offered by RUF Briquetting Systems,[41] can convert loose woody waste material in uniform-sized briquettes that are easy to store and transport to market.

Results show that this briquetting system increases the volumetric energy density of chipped biomass by nearly 250%, producing briquettes with an average density of 45 pounds per cubic foot. Feedstocks with moisture content exceeding 15% produce lower density briquettes, which expand in height after exiting the briquette press. High moisture content, however, does not significantly impact briquette durability. Instead, the feedstock's particle size distribution has the greatest effect on briquette durability. Feedstocks comprising mainly large particles, especially chipped biomass, do not bind together as well as fine or ground particles. To improve durability, chipped biomass can be combined with sawdust, which increases briquette durability two-fold and results in briquettes with a binding strength similar to those produced from pure sawdust.

TSS interviewed a company operating a portable briquetting machine that sourced woody feedstocks as raw material in Arizona.[42] The operator uses a RUF Briquetting Systems Model 600 directly in the forest environment sourcing PJ material and other wood species, along with bark and needles. The unit weighs about 9,600 pounds and is set up on a portable frame to be able to utilize the wood waste coming from field-based projects. Marketing of the briquette product from this operator has been principally by word of mouth.

Wood waste briquetting could meet some of the critical attributes impacting economic operations. In regard to minimum scale, briquetting using portable units, taken to the field, could be likely accomplished at the lower end of the volume spectrum. As the end-market further absorbs the product, briquetting units can increase in number and/or volume output to utilize even more forest and grassland-based wood waste. Discussions with the field operator confirmed that the briquetting unit could use most of the wood waste generated as a byproduct of fuels reduction or grassland restoration projects if material generated is sized at four inch minus.

Wood-fired residential heating is a relatively large and robust market in the Southwest United States. Wood briquettes could impact the cord wood markets by substituting briquettes for cordwood. Transportation cost to markets could be lower than cordwood due to the densification factor in briquetted wood waste.

[41] https://www.ruf-briquetter.com
[42] Gary Snider, Predera Madera, Lakeside, Arizona.

Representative Vendor

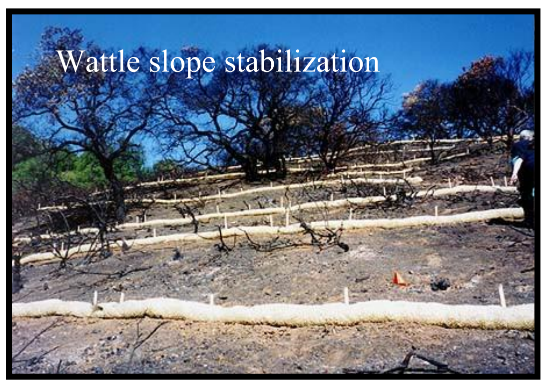
Pradera Madera (Savanna Wood) – Lakeside, AZ
Gary Snider, praderamadera@gmail.com

<u>Storm Water Wattles (Wood Chips)</u>

A sediment retention fiber roll (SRFR) is a manufactured 3-dimensional device of a specified filler material encapsulated within a flexible containment material utilized in sediment and flow control applications. SRFRs are also known as wattles, logs, socks, tubes or fiber rolls and are offered as a prefabricated unit. The flexible containment material can be biodegradable materials (as are the wood chips used as filler).

Wattles are useful for the following reasons:

- Control storm water runoff. Diverts flow and directs storm water to treatment areas.
- Prevent off-site sedimentation at active construction sites. Keeps soil on-site and prevents it from washing onto pavement and asphalt; an economical and effective perimeter control alternative to silt fence and straw bales.
- Protect against slope erosion. Wattles work to reduce the erosive effects of slope length and steepness; the product is even more effective when installed in combination with hydraulic or rolled erosion control products.
- Capture inlet sedimentation. When wrapped around storm drain inlets, protects area drains and storm drain inlets from fast water flow and sediment.
- Promote stabilization and revegetation of stream banks and shorelines. Wattles prevent sediment pollution of streams and are a complementary component for soil bioengineering projects.
- Provide soil stabilization for forest fire rehabilitation. Wattles slow the velocity of rain runoff and help to prevent rill and gully slope erosion by holding bare soil in place and trapping ash and sediment.



Wattles can be composed of various types of straw or wood chips. Wood chip wattles can offer certain advantages over straw wattles[43] such as:

- they weigh more than straw wattles and therefore do not need heavy staking;
- no trenching is required due to heavier weight;
- heavier weight eliminates undermining by surface flow;

[43] Ecowattles from Texas Sustainable Industries. See: http://ecowattle.com/wp-content/uploads/2010/11/EcoWattle-Product-Information-web.pdf

- useable on paved surfaces;
- can be stacked.

Wood chip wattles weigh approximately 8 pounds per linear foot with a 12-inch diameter. Thus, the common length of 10 feet results in wood chip wattle weight of approximately 80 pounds compared to a 10-foot straw wattle weight of approximately 35 pounds.

There also exists the potential to add biochar to wood chip wattles which may increase their beneficial value at filtering storm and run-off water. The UVRWPC is conducting trials over the next two years with local partners and mine/quarry operators to examine the effectiveness of juniper chip wattles blended with biochar for contaminant filtration in waterways, and heavy metal filtration at mine and quarrying sites.

Representative Vendors

CDW Consultant Group – Victoria, TX
dwhite@cdwconsultants.com

Texas Sustainable Industries, LLC – Tyler, TX
Ecowattle.com

Biomass Conversion Technologies Review Matrix

Based on the research and findings of the woody biomass technologies discussed above, a matrix of those technologies and important factors for each of the technologies was presented below to assist the UVRWPC in selecting two technologies for further economic analysis. The following factors addressed in the matrix are:

- Commercial availability
- Feedstock requirements
- Job creation
- Market potential
- Water supply and wastewater disposal
- Noise
- Relative air emissions
- Commercial production

In preparing the matrix, it is assumed that approximately 25,000 BDT per year of feedstock generated as a byproduct of fuels reduction and restoration activities on forestland and grassland would be readily available. This could scale up linearly if additional feedstock is acquired. Table 9 is the technology review matrix.

Table 9. Technology Review Matrix

Conversion Technologies	Selection Factors[1]			
	Commercial Availability	**Feedstock Requirements**	**Job Creation[2]** (Full time employees at production facility)	**Market Potential**
Industrial Grade Fuel Pellets	Very commercial, over 17,000,000 tons per year produced in the U.S. and Canada.	Industrial grade fuel pellets can use low-grade wood fiber, tops and limbs, commercial thinnings, and mill residues.	~15	Potential for co-fire with coal. Larger scale gives access to international markets for co-firing and stand-alone biomass plants.
Torrefied Fuels	There are a few U.S. companies producing relatively small amounts of torrefied fuels.	Can use a wide variety of woody biomass feedstocks yielding similar product properties.	25 to 30	Co-firing in power plants using coal (no modifications needed for use of torrefied fuel). However, coal sets the market price point.
Bio-Coal Enginuity	Currently only has demonstration plant.	Can use a wide variety of woody biomass feedstocks yielding similar product properties.	25 to 30	Co-firing in power plants using coal (no modifications needed for use of Enginuity bio-coal). However, coal sets the market price point.
Biochar	Several companies producing relatively small amounts of biochar.	Can use a wide variety of woody biomass. Physical and chemical differences in biochar product may occur depending on feedstock (e.g., species of wood).	10 to 12	Appears to be growing as soil amendment, with potential for many other uses such as water and air filtration.
Fuel Bricks	Commercial equipment available to make fuel bricks.	According to fuel brick maker, can use all of the forest wood residues – wood, bark, and needles if sized correctly.	7 to 12 (depending on size and number of briquetting machines used to process 25,000 BDT/year)	Substitute for firewood is the principal market.
Wattles	Commercially available.	Preference is for bark and needle free wood chip (paper and pulp quality).	6 to 10 (depending on capacity and number of wattle forming machines used to process 25,000 BDT/year)	Widespread use for controlling storm water runoff at construction sites, slope stabilization, and erosion control.

1 – Conversion of approximately 25,000 BDT of economically available woody biomass
2 – Does not include in-field jobs

Conversion Technologies	Selection Factors[1]			
	Water Supply and Wastewater Disposal	**Noise[2]**	**Relative Air Emissions**	**Commercial Production**
Industrial Grade Fuel Pellets	No significant water usage. No wastewater disposal.	Low	Low	90%-plus of the current economically available feedstock could be converted to industrial grade fuel pellets. This would result in 22,500 tons of product per year. 35 of the 148 pellet plants reported in the U.S. produce less than this amount.
Torrefied Fuels	No significant water usage. No wastewater disposal.	Low	Low	Up to 70% of feedstock could be converted to torrefied fuel, which would be approximately 17,500 tons per year of torrefied fuel.
Bio-Coal Enginuity	No water usage. No wastewater disposal.	Low	Low	Up to 80% of feedstock could be converted to bio-coal, which would be approximately 20,000 tons per year of biocoal.
Biochar	No water usage. No wastewater disposal.	Low	Low	Up to 30% of feedstock could be converted to biochar, which would be approximately 7,500 tons per year of biochar product. Production facilities can be centralized, decentralized, and mobile.
Fuel Bricks	No water usage. No wastewater disposal.	Very low	None, if operating on electricity only	90%-plus of current economically available feedstock could be processed into fuel bricks. Size and number of fuel bricks is dependent on briquetting machine used.
Storm Water Wattles	No water usage. No wastewater disposal.	Very low	None, if operating on electricity only	Wood chip wattles require appropriately sized wood chips. Smaller branches may not meet the size requirements, nor can needles and duff be used. It will need to be determined what percentage of economically available feedstock could be processed into wood chips appropriate for the wattles.

1 – Conversion of approximately 25,000 BDT of economically available woody biomass
2 – Assumes facility is in a structure, with outside storage of feedstock

ECONOMIC ANALYSIS

Introduction

In 2016, TSS Consultants (TSS) conducted a biomass feedstock supply availability assessment for the Coalition.[44] In the assessment it was determined that ongoing and planned thinning and removal operations of juniper, pinyon pine, and ponderosa pine to reduce catastrophic wildfire potential, restore former grasslands wildlife habitat, and improve watershed conditions would result in the production of excess woody biomass material. This excess woody biomass could be used by a variety of biomass conversion technologies with the potential establishment of a woody biomass conversion facility in Yavapai County, Arizona. Biomass conversion technologies that could potentially convert this excess woody biomass to value-added products are presented below.

- Industrial-grade fuel pellets
- Torrefied fuels
- Bio-coal (Enginuity Process)
- Biochar and activated carbon
- Fuel bricks
- Storm water wattles with wood chips and biochar

Utilizing the UVRWPC project team input, a selection of preferred conversion technologies was made based on the following feedstock findings.

- Approximately 25,000 BDT/year of wood waste economically available from PJ grasslands restoration and fuels treatment activities.
- This volume could expand to over 100,000 BDT/year if local biomass markets existed.
- Average cost of delivered feedstock would be approximately $65/BDT.[45]
- Delivered feedstock would be in the 15 to 25% moisture content range.

Ultimately, biochar and storm water wattles with wood chips and biochar were selected as the most promising technologies based on the system's flexibility, state of the industry, and market risk. Summarized below are the potential market opportunities for these technologies, along with a high-level economic analysis of biochar and wood chip wattles using woody biomass resources of central Arizona.

---

[44] Biomass Feedstock Supply Availability Assessment for Yavapai County, TSS Consultants, October 2016.
[45] This cost assumes in the first 10 years there would be a focus on operating in the mid to high-density stands of pinyon pine and juniper.

Market Opportunities

Biochar Uses

The production of biochar has been previously discussed in the Conversion Technology Review section, with some lesser discussion of the market opportunities for biochar. Biochar's unique properties, such as low density (providing additional voidage and aeration in soil and other solid materials) and significant adsorption and cation exchange capacity, can be exploited in many ways and many uses as listed below.

Soil amendment

- Carbon fertilizer;
- Compost;
- Substitute for peat in potting soil;
- Plant protection;
- Compensatory fertilizer for trace elements.

Livestock farming

- Silage agent;
- Feed additive/supplement;
- Litter additive;
- Slurry treatment;
- Manure composting;
- Water treatment in fish farming.

Decontamination of soil and water

- Soil additive for soil remediation;
- Highly adsorbent, plantable soil substrates;
- Barrier preventing pesticides contamination into surface water;
- Treating pond and lake water.

Water, wastewater and sewage treatment

- Active carbon filter;
- Pre-rinsing additive;
- Soil substrate for organic plant beds.

Exhaust filter

- Controlling air emissions (including odor);
- Room air filters.

Building material

- Insulation;
- Air decontamination;
- Decontamination of earth foundations;
- Humidity regulation;

- Protection against electromagnetic radiation ("electrosmog"[46]).

Other uses

- Industrial materials – carbon fibers, plastics;
- Electronics – semiconductors, batteries;
- Metallurgy – metal reduction;
- Cosmetics – soaps, skin cream, therapeutic bath additives;
- Paints and coloring – food colorants, industrial and commercial paints;
- Energy production – pellets;
- Medicines – detoxification, carrier for active pharmaceutical ingredients.

The market for biochar is in an emergent mode and suffering from the "chicken or the egg" syndrome. There have not been sufficient reliable suppliers of biochar products to date to allow the demonstration of the at-scale value propositions in specific biochar markets. Thus, the issue of how cost effective biochar is in specific markets such as wastewater filtration and treatment is still largely unresolved, although studies are accumulating in the literature[47] and within individual industrial demonstration scale projects. Furthermore, in the absence of specific market opportunities that demonstrate the value of biochar, financing biochar production capacity continues to be a challenge. There are indications nonetheless that the development gridlock is slowly being resolved and definitive growth in biochar capacity and adoption is anticipated over the next decade.[48]

In Arizona, specifically, the biochar market opportunities could be significant. The Arizona agricultural sector (a $12 billion-plus industry) is the largest consumer of water in the state and will continue to be for the foreseeable future. Biochar's water retention capacities could make it a prime product for use in sandy loam soils typically found in Arizona's agricultural fields. The University of Arizona[49] continues to conduct research in the use of biochar in the Arizona agricultural industry.

Another potentially large market for biochar in Arizona is in mine reclamation and cleanup, as there are numerous mining sites in the state. It has been reported that there are 10,000 abandoned mine sites alone in Arizona.[50] Significant and enduring problems associated with mining affected sites include the transport of acidic and heavy metal rich

---

[46] Electrosmog is the invisible electromagnetic radiation resulting from the use of both wireless technology and main electricity.
[47] Thompson, Kyle A. et al. *Environmental Comparison of Biochar and Activated Carbon for Tertiary Wastewater Treatment*, Environmental Science and Technology, 2016;
Rasheed, A. et al. *To Evaluate the Efficiency of Char and Biochar for Wastewater Treatment*, Journal of Waste Recycling, October 2017;
Huggins, Tyler M. et al. *Granular Biochar Compared with Activated Carbon for Wastewater Treatment and Resource Recovery,* U.S. Navy Research 99, 2016;
Abdel-Fattaha, T. et al. *Biochar from Woody Biomass for Removing Metal Contaminants and Carbon Sequestration*, Journal of Industrial and Engineering Chemistry, 2015.
[48] Groot, H. et al. *Biochar as an Innovative Wood Product: A Look at Barriers to Realization of Its Full Potential*, Dovetail Partners, 2017.
http://www.dovetailinc.org/report_pdfs/2017/dovetailbiocharpotential0517.pdf
[49] See: https://www.arizona.edu/search/google/biochar
[50] 2016 Annual Report to the Governor, Joe Hart, Arizona State mine inspector..

materials into watercourses. Biochar could be utilized as both a filtration agent for heavy metals, as well as a soil amendment to foster healthy vegetative cover and soil conditions, which can mitigate the transport of contaminated soils off site from active or retired mining operations.

Biochar can also be upgraded to an activated carbon product (as discussed in the Conversion Technology Review section). In summary, that discussion indicated that activated biochar could be used in wastewater treatment plants and command even higher prices, as traditional activated carbon can be in excess of $3,000 per ton.[51] There are over 125 permitted wastewater treatment plants in Arizona and over 900 wastewater treatment plants in neighboring California.

Wood Chip Wattles (With and Without Biochar)

The interest in the use of wood chip wattles (particularly when biochar is added) in central Arizona is high, and their use in other areas of the state is also potentially high.[52] They are particularly applicable to mining sites, as well as construction sites for storm water management, heavy metal filtration, and prevention of non-point source water pollution. The U.S. Forest Service recently awarded the Arizona Department of Forestry and Fire Management (DFFM) a Wood Innovations grant to demonstrate the use of juniper wood chip wattles blended with biochar for heavy metal filtration and storm water management in open pit mining and quarrying operations. The UVRWPC will implement a significant portion of the work with the other project partners, and along with the fieldwork to demonstrate the effectiveness of biochar-infused juniper wood chip wattles, will further examine the market potential in the state of Arizona. The UVRWPC, along with the DFFM, will develop marketing materials, mining industry outreach, and a public information campaign.[53]

The market potential for woodchip wattles in storm water management could be significant and includes:

- Construction sites;
- Road building (will eventually require inclusion on the ADOT approved product list for full development);
- Landscaping;
- Post-fire remediation for storm water only, not soil remediation;
- Mining for storm water only, not filtration;
- Erosion control.

Blending biochar with juniper chips can increase the market potential for various activities such as:

[51] See: https://www.alibaba.com/showroom/coconut-activated-carbon-price-per-ton.html
[52] Personal communication with Melody Reifsnyder, Upper Verde River Watershed Protection Coalition, May 29, 2018.
[53] From the U.S. Forest Service Wood Innovations Application – FY 2018, Demonstration of Juniper Chip Wattles Blended with Biochar for Heavy Metal Filtration and Stormwater Management in Open Pit Mining and Quarrying Operations.

- Remediate high Total Maximum Daily Load[54] (TMDL) and *E. Coli* bacteria concentrations in waterways.
- Heavy metal filtration at open pit mine and quarrying sites (including operational and abandoned mines).
- Soil remediation on agricultural lands and post-fire landscapes (pollutant load reductions of nitrogen and other fertilizer runoff that contributes to the overgrowth of algae which has been proven to cause increased bacterial development and create dangerous situations for the health of aquatic plants and animals).

Currently the UVRWPC is implementing projects that involve wattle installation:

- Erosion control on agricultural land;
- Storm water management at mining sites;
- *E. Coli* bacteria filtering at Granite Creek;
- Purchase of wattles by Yavapai County Public Works and the Coalition that will be stored for future use.

Several other wood chip wattle projects are in development with the UVRWPC, two of which include working with Yavapai County for *E. Coli* filtering at Manzanita Creek and with Yavapai County Flood Control, purchase and utilization of wood chip wattles for post fire remediation.

The biggest market threat to full market development of juniper wood chips (with or without biochar infusion) is the cost of the wattles themselves. Even at $2.50 per linear foot, they are more expensive than traditional straw-based wattles. However, juniper chip wattles are more durable than straw, so replacement costs will be lower. Wood chip wattles are more durable and long lasting and are also not broken open and eaten by range cattle.[55]

An additional (and non-monetary) threat is government agency and private sector inability to adjust to a new product. Currently, agencies such as the Arizona Department of Transportation and others are comfortable with straw wattles, with which they have had a long history of use.[56] When such entities do allow for woody biomass, they have required excelsior-type wood fiber, which mimics straw. Education regarding the significant added value of wood chip wattles is paramount. The UVRWPC can be a valuable asset in the development of this education and a market strategy (with cost analysis). Recent funding from the Wood Innovations grant will support this particularly important strategy initiative. This grant will fund field trials of biochar infused wood chip wattles at the Freeport-McMoran Bagdad Mine, an open pit copper mine in Bagdad,

[54] A TMDL is the calculation of the maximum amount of a pollutant allowed to enter a water body so that the water body will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.
[55] Personal communication with Melody Reifsnyder, UVRWPC, May 29, 2018.
[56] Ibid.

Arizona (approximately 60 miles west of Prescott), and a limestone quarry managed by Drake Cement in Paulden, AZ (approximately 40 miles north of Prescott).[57]

Economic Analysis

TSS worked with biochar and wood chip wattle technology vendors to understand the capital costs and operational parameters of the proposed facilities at two scales of raw material usage: 25,000 BDT/year and 100,000 BDT/year. As TSS maintains non-disclosure agreements with these technology vendors, their names are not included in this report document to shield confidential information.

Biochar Production

Capital costs of a biochar production facility are summarized in Table 10.

Table 10. Capital Cost Estimate for a Biochar Production Facility

	Capital Costs		
	Facility Size	**25,000 BDT/yr**	**100,000 BDT/yr**
System Components	Conversion System	\$4,250,000	\$14,750,000
	Building	\$1,500,000	\$2,000,000
	Feedstock Storage & Processing	\$500,000	\$750,000
	Construction/Installation	\$1,250,000	\$3,500,000
	Total	**\$7,500,000**	**\$21,000,000**

In addition to the capital costs, operational parameters included:

- Annual Operations: 2 shift, 300 days per year
- Full Capacity Uptime: 80%
- Biomass Delivered Cost: \$65/BDT
- Biochar Production: 30% of incoming feedstock
- Labor: 18 employees (25,000 BDT/yr); 35 employees (100,000 BDT/yr)[58]
- Annual Maintenance: 10% of capital cost
- Utilities: 150 kWh per BDT processed
- Federal Tax Rate: 34.6%
- State Tax Rate: 6.968%
- Inflation: 2.0%
- Debt Ratio: 50%
- Interest Rate: 6%
- Debt Term: 10 years
- MACRS[59] Depreciation: 7 years

[57] From the U.S. Forest Service Wood Innovations Application – FY 2018, Demonstration of Juniper Chip Wattles Blended with Biochar for Heavy Metal Filtration and Stormwater Management in Open Pit Mining and Quarrying Operations.
[58] This is in addition to employment in the field harvesting, processing, and transporting the biomass feedstock – 9 jobs for 25,000 BDT/year to 36 jobs for 100,000 BDT/year.
[59] Modified Accelerated Cost Recovery System is the current tax depreciation system used in the United States. Under this system, the capitalized cost (basis) of tangible property is recovered over a specified time period by annual deductions for depreciation.

To determine the financial viability, TSS varied biochar market price (FOB production facility) to evaluate the financial returns. Beginning at a minimum price identified at a 0% internal rate of return (IRR), the results are shown in Table 11 and Table 12. The simple payback period (SPP) in years is also included.

Table 11. Financial Results for 25,000 BDT/Yr Biochar Production Facility

Biochar Market Price ($/BDT)	Internal Rate of Return	Simple Payback Period
$708	0%	20
$800	**16.4%**	**5.5**
$1,000	42.8%	2.2
$1,400	91.0%	1.0

Table 12. Financial Results for 100,000 BDT/Yr Biochar Production Facility

Biochar Market Price ($/BDT)	Internal Rate of Return	Simple Payback Period
$527	0	20
$600	**18.0%**	**5.2**
$800	54.7%	1.7
$1,000	89.0%	1.0
$1,400	156.0%	0.6

With the baseline target of $800/BDT of biochar produced at the 25,000 TPY facility and $600/BDT of biochar at a 100,000 BDT/year facility, the price needed for an internal rate of return that should attract investment (a minimum of 15%) is consistent with wholesale market price considering the current market rate for biochar (up to $800 a bulk ton) in the west.[60] It should be noted, however, that the biochar market in the United States is still relatively small, and fluctuations in the price of biochar and accessibility to the marketplace could be challenging.

To understand the sensitivity of the financial model to changing assumptions, TSS evaluated the impacts of changes to key baseline assumptions. As shown in Table 13, operating costs—driven by maintenance, utility cost, and administrative costs—are the most important variable to understand as they have the greatest impact on the financial model results for the 25,000 BDT/year facility. Remaining variables, including capital cost, labor cost, and feedstock cost, are all significant components of the overall financial model, with considerable implications if there are deviations from the baseline assumptions.

[60] Personal communication with Tom Miles, TR Miles Technical Consultants, July 28, 2018. Mr. Miles is also a Board Member of the International Biochar Initiative.

Table 13. Results for 25,000 BDT/Yr Biochar Facility @ $800/BDT Market Price

Sensitivity	Internal Rate of Return	Simple Payback Period
Baseline (@ $800/BDT)	16.4%	5.5
Capital Cost (20% increase)	9%	8.6
Labor Costs (20% increase)	8.5%	9.1
Operational Costs (20% increase)	6.5%	10.7
Feedstock Costs (20% increase)	9.6%	8.4

Table 14. Results for 100,000 BDT/Yr Biochar Facility @ $600/BDT Market Price

Sensitivity	Internal Rate of Return	Simple Payback Period
Baseline (@ $600/BDT)	18.0%	5.2
Capital Cost (20% increase)	10.8%	7.9
Labor Costs (20% increase)	13.0%	6.9
Operational Costs (20% increase)	8.0%	9.6
Feedstock Costs (20% increase)	8.5%	9.3

Table 14 shows a similar trend as in Table 13 with operational costs being the most sensitive variable to the financial model. The importance of feedstock costs increased as the facility size grew with the importance of labor costs decreasing with facility size.

At both scales (25,000 BDT and 100,000 BDT), capital costs were secondary to operational costs, stressing the importance of value engineering and investment in capital infrastructure that will ease the operational burdens of the plant.

<u>Wood Chip Wattle Production</u>

Capital costs of system components for a wood chip wattle production facility are presented in Table 15.

Table 15. Capital Cost Estimate for Wattle Production Facility

	Capital Costs		
System Components	**Facility Size**	**25,000 BDT/yr**	**100,000 BDT/yr**
	Conversion System	$4,750,000	$10,500,000
	Building	$1,500,000	$6,000,000
	Feedstock Storage & Processing	$250,000	$500,000
	Construction/Installation	$1,00`0,000	$3,000,000
	Total	**$7,500,000**	**$20,000,000**

In addition to the capital costs, operational parameters included:

- Annual Operations: 2 shift, 300 days per year
- Full Capacity Uptime: 80%
- Biomass Delivered Cost: $65/BDT
- Wattle Density: 20 lb/linear foot
- Labor: 14 employees (25,000 BDT/yr); 52 employees (100,000 BDT/yr)[61]
- Annual Maintenance: 20% of capital cost
- Utilities: 150 kWh per BDT processed
- Federal Tax Rate: 34.6%
- State Tax Rate: 6.968%
- Inflation: 2.0%
- Debt Ratio: 50%
- Interest Rate: 6%
- Debt Term: 10 years
- MACRS Depreciation: 7 years

To determine financial viability, TSS varied the wattle market price (FOB production facility) to evaluate the financial returns. Beginning at a minimum price identified at a 0% IRR, the results are shown in Table 16 and Table 17. The simple SPP in years is also included.

[61] This is in addition to employment in the field harvesting, processing, and transporting the biomass feedstock – 9 jobs for 25,000 BDT/year to 36 jobs for 100,000 BDT/year.

Table 16. Financial Results for 25,000 BDT/Yr Wattle Production Facility

Wattle Market Price ($/ft)	Internal Rate of Return	Simple Payback Period
$2.51	0%	20
$2.75	14.8%	6.1
$3.00	**26.5%**	**3.5**
$3.50	47.7%	1.9
$4.00	67.9%	1.3

Table 17. Financial Results for 100,000 BDT/Yr Wattle Production Facility

Wattle Market Price ($/ft)	Internal Rate of Return	Simple Payback Period
$2.00	0	20
$2.25	**20.9%**	**4.4**
$2.50	37.3%	2.5
$3.00	68.0%	1.3
$3.50	97.7%	0.6

The baseline target for a 25,000 BDT per year facility was identified to be $3.00/ft and for a 100,000 BDT per year facility, the baseline target was identified to be $2.25/ft. The baseline target was determined using a minimum internal rate of return of 15%, which should be sufficient to attract external investment. It should be noted that the majority of the wattle market uses straw-type filler with prices substantially below that of the identified wood wattle prices (~$0.70-$1.30/ft).[62] Understanding the demand for wood wattles in the region will be an important factor to consider prior to investment in a commercial scale wattle manufacturing facility.

To understand the sensitivity of the financial mode to changing assumptions, TSS evaluated the impacts of changes to key baseline assumptions. As shown in Table 18, operating costs—driven by maintenance, utility costs, and administrative costs—is the most important variable to understand as it has the greatest impact on the financial model results for the 25,000 BDT/year facility. Capital cost is clearly the second most sensitive of the variables with labor and feedstock costs identified as less impactful cost components. The wattle manufacturing process is reported to have operational costs equal to 20% of the capital cost,[63] which is significantly higher than the operational cost estimates for the biochar facility.

[62] Market research conducted by TSS Consultants.
[63] Personal communications with Don White, CDW Consulting, Victoria, TX.

Table 18. Sensitivity for 25,000 BDT/Yr Wattle Facility @ $3/Ft Market Price

Sensitivity	Internal Rate of Return	Simple Payback Period
Baseline (@ $3.00/ft)	26.5%	3.5
Capital Cost (20% increase)	15.5%	5.8
Labor Costs (20% increase)	21.6%	4.3
Operational Costs (20% increase)	10.9%	7.7
Feedstock Costs (20% increase)	20.6%	4.5

Table 19. Sensitivity for 100,000 BDT/Yr Wattle Facility @ $2.25/Ft Market Price

Sensitivity	Internal Rate of Return	Simple Payback Period
Baseline (@ $2.25/ft)	20.9%	4.4
Capital Cost (20% increase)	10.1%	8.1
Labor Costs (20% increase)	13.0%	6.7
Operational Costs (20% increase)	4.4%	12.8
Feedstock Costs (20% increase)	11.3%	7.5

Table 19 shows a similar trend as in Table 18 with operational costs being the most sensitive variable to the financial model. At the larger scale (100,000 BDT per year), the financial model is more sensitive to changes in operational and labor costs versus capital costs than with the smaller facility. This finding demonstrates the advantages of economies of scale when evaluating a larger scale facility.

In both cases, capital costs were secondary to operational costs, stressing the importance of value engineering and investment in capital infrastructure that will ease the operational burdens of the plant.

<u>Biochar and Wood Chip Wattle Production</u>

TSS also conducted an analysis to determine if simultaneous investment in a biochar facility and wattle facility was appropriate. Investing in a synchronized model incorporating both conversion technologies dramatically increases the financial risk. One of the most important decisions in this scenario is understanding how to optimize the flow of available wood. To do so, TSS calculated wood flows based on 25,000 BDT/year availability and 100,000 BDT/year availability (Table 20 and Table 21).

Table 20. Feedstock Flow for 25,000 BDT/Yr Availability

Biochar Ratio	Raw Wood to Biochar	Resulting Biochar	Raw Wood to Wattle	Total to Wattle (Raw + Biochar)
No Biochar	0	0	25,000	25,000
10%	6,760	2,030	18,240	20,270
20%	11,360	3,400	13,640	17,040
50%	19,230	5,770	5,770	11,540
All Biochar	25,000	7,500	0	7,500

Table 21. Feedstock Flow for 100,000 BDT/Yr Availability

Biochar Ratio	Raw Wood to Biochar	Resulting Biochar	Raw Wood to Wattle	Total to Wattle (Raw + Biochar)
No Biochar	0	0	100,000	100,000
10%	27,040	8,120	72,960	81,080
20%	45,440	13,600	54,560	68,160
50%	76,920	23,080	23,080	46,160
All Biochar	100,000	30,000	0	30,000

When considering the investment in biochar and wood/biochar wattle blends, it is critical to understand regional demand. A decision to invest in both technologies to produce biochar/wood wattles would require a significant price premium over the wood wattle product. With the biochar feedstock costing nearly 15 times that of wood (this assumption pegs wood at $65/BDT and biochar at $975/BDT), it is important to understand minimum blend levels that achieve the target performance advantage (of biochar/wood wattles over wood-only wattles). See previous discussion addressing local markets.

To illustrate the point, TSS developed Table 22 based on the data from Table 20 showing a simplified understanding of the cost/revenue impacts of the level of biochar blend. The Biochar Cost column is the product of the "Resulting Biochar" column of Table 20 $975/BDT, the Wood Cost column is the product of the "Raw Wood to Wattle" column of Table 20 and $65/BDT, the Wattle Production column is the "Total to Wattle" column of Table 20 multiplied by 2,000 lb/ton and divided by the wattle density of 20 lb/linear foot.

Table 22. Feedstock Flow for 25,000 BDT/Yr Availability

Biochar Ratio	Biochar Cost	Wood Cost	Total Feedstock Cost	Wattle Production (lf)	Feedstock Cost/lf Wattle
No Biochar	$0	$1,625,000	$1,625,000	2,500,000	$0.65
10%	$1,979,250	$1,185,600	$3,164,850	2,027,000	$1.56
20%	$3,315,000	$886,600	$4,201,600	1,704,000	$2.47
50%	$5,625,750	$370,500	$5,996,250	1,154,000	$5.20
All Biochar	$7,312,500	$0	$7,312,500	750,000	$9.75

As the percentage of biochar increases, the relative expense of the feedstock increases dramatically. This is exacerbated by the constrained wood supply (the analysis assumes that there is only 25,000 BDT/year available). The impacts are far less dramatic if there is additional supply (e.g., build manufacturing capacity for 25,000 BDT/year but actually have 100,000 BDT/year of feedstock available).

With the additional levels of risk and uncertainty that comes with an investment in a biochar-wood chip wattle manufacturing line, TSS recommends that the biochar and wood wattle manufacturing systems be evaluated as completely independent business entities. Using this approach, each business would be able to stand alone with its own independent markets. If ultimately a premium for biochar-wood wattles is found, there could be value to having the two enterprises located adjacent to each other and possibly share infrastructure, labor and rolling stock.

If investment in both facilities moves forward as independent but parallel paths, Table 20 and Table 21 would provide appropriate calculations to consider for facility scale (to allow both facilities to develop simultaneously). The downside of this approach is that each individual facility would be smaller than they would otherwise be if only one entity was considered, and some economies of scale (including sharing of infrastructure, labor and rolling stock) would be lost.

RECOMMENDATIONS

Biochar and Wood Chip Wattle Production

Both the biochar and wood chip wattle markets in Arizona are not well defined. Discussions with wattle producers and Coalition representatives confirm that the current, relatively nascent market for wattles has significant upside potential. Both parties feel that a potential market opportunity for these products is mine reclamation activities within Arizona. Numerous mining operations focused on the extraction of copper, molybdenum, Portland cement, sand/gravel, pumice, perlite, salt, crushed stone and lime have been retired. The 2016 report to the governor by the Arizona State mine inspector noted that approximately 10,000 abandoned mines have been inventoried statewide.[64]

[64] 2016 Annual Report to the Governor, Joe Hart, Arizona State mine inspector.

Over the next two years, the Coalition, with grant funding from the US Forest service, is conducting proof of concept trials to examine the effectiveness of juniper chip wattles blended with biochar. Testing sites included working and abandoned mines and/or open pit quarry sites in Yavapai County.

The capital expense for development of a wood chip wattle production facility is significant at $7,500,000. TSS anticipates that private financial markets will be reluctant to participate in debt financing of a facility producing a commodity with a relatively unknown end market. A critical step in achieving long-term debt financing is securing long-term offtake agreements for the commodity produced.

Bioenergy Initiatives

Several bioenergy initiatives are underway in northern Arizona including request for proposals issued by two large Arizona utilities: Salt River Project and Arizona Public Service. Both of these utilities are familiar with biomass power generation and the significant societal benefits (forest health, fuels reduction, employment) that result from deployment of commercial-scale facilities (such as Novo BioPower in Snowflake). The Coalition should continue to monitor the results of these requests for proposals.

In addition, the Arizona Department of Emergency and Military Affairs (AZDEMA) in conjunction with Coconino County, the Arizona Department of Forestry and Fire Management, and the USFS are sponsoring a feasibility study to assess the potential opportunity to site a commercial-scale bioenergy facility at Camp Navajo. The Camp is strategically located on a major highway (Interstate 40) and a major railway (Burlington Northern Santa Fe), plus has access to water and natural gas. PJ material from northern Yavapai County could be within economic transport distance of a bioenergy facility sited at Camp Navajo.

APPENDIX A. ARIZONA DEPARTMENT OF TRANSPORTATION HEALTHY FOREST PERMIT PROCESS

ADOT

Janice K. Brewer, Governor
John S. Halikowski, Director

Healthy Forest Permit Process

ADOT currently uses the TransPort system to issue over dimensional permits. As of December 8, 2014, ADOT will begin using the ADOT ePro system to issue over dimensional permits. To provide consistency for Healthy Forest Initiative timber haulers during the system transition period, ITD and ECD have devised a plan to initiate permits for the pilot project immediately.

ADOT will provide Eastern Arizona Counties with permit applications and a step by step process of the following:

1. Timber haulers will submit a paper application and check payment of $75 for each power unit to Central Permits (Goodyear Office) in order to obtain a 30 day permit for each power unit.
2. Central Permits will issue the 30 day permits out of the TransPort system. The permit will detail specific routes authorized for travel, safety measures specific to load dimensions that must be adhered to during transport and allow movement up 90,800lbs. The permit will also include standard language which states the ADOT permit is valid for ADOT listed routes only and movement on local roads must be approved by the local jurisdiction(s).
3. Once the permits are received by the haulers they may begin transport on the ADOT approved routes.
4. Haulers will be required to submit a weekly record of loads travelled under each permit. The permit number, origin, destination and weight of each load moved under the permit will be listed. The weekly record will be sent to the HealthyForest@azdot.gov . The information provided by the haulers will be used to support reporting requirements for FHWA Size and Weight Certification Standards.
5. Once the ePro system is implemented on December 8th, the haulers can submit their applications and pay for their permits online. The new system includes the option to copy and resubmit a previously approved application, submit applications for future dates and submit trip authorizations (tracking of each load moved) online. ADOT will provide a step by step screen print process for the haulers to help them establish their account and begin submitting their applications on the ePro system.

For information, contact:

Jennifer Cannon
Manager, Maintenance Permits Services
206 South 17th Avenue, MD 004R
Phoenix, AZ 85007
JCannon@azdot.gov
602-712-4142
www.azdot.gov

ADOT

APPENDIX B. SALT RIVER PROJECT RENEWABLE ENERGY REQUEST FOR PROPOSALS

Salt River Project

2018 Request for Proposals for Renewable Energy Projects

I. Purpose and Scope

Salt River Project Agricultural Improvement and Power District ("SRP") is requesting competitive proposals for a power purchase from parties who can develop a renewable energy project. SRP is seeking a total capacity of 100 MW.

SRP is an agricultural improvement district organized under the laws of the State of Arizona, and provides retail electric service to more than 1 million residential and business customers in and around the Phoenix metropolitan area. SRP serves the energy needs of its customers from generation that is produced with a diverse fuel mix that includes nuclear, coal, hydroelectric, natural gas, and renewable resources including solar, wind, biomass, and geothermal. SRP is rated AA by Standard & Poor's Corporation and Aa1 by Moody's Investors Services, Inc. and is headquartered in Tempe, Arizona.

SRP has a strong history of stewardship associated with the water and power resources it provides to the Salt River Valley and a strong commitment to the environment. In keeping with both of these traditions, it is SRP's objective to expand its use of environmentally sensitive supply side options, explore additional ways to displace the use of fossil fuels, provide opportunities for the introduction of new technologies and ideas, and reduce our carbon intensity.

Projects elected under this Request for Proposals will help SRP expand customer-dedicated green energy programs for large commercial and industrial customers.

II. Requested Proposal

SRP is requesting proposals for renewable energy projects up to 100 MW in size. Smaller size projects will be considered, but must have a minimum size of 25 MW. SRP is targeting projects that can be delivered to the SRP transmission system with a commercial operation date of December 31, 2020. All bids must include a proposal for a long-term (25 year) power purchase agreement ("PPA"). Solar, wind, geothermal, and biomass projects will be considered. Proposals with a battery storage component are also encouraged (as long as an alternative proposal without storage is also provided). SRP will not consider hydro or landfill gas resources under this RFP. In addition, SRP will only accept proposals for new renewable energy projects. Detailed descriptions of these requested proposals can be found in Sections XIII. SRP will review proposals relative to the current resource plan and may elect to not pursue an agreement.

All bids will be required to provide the information and descriptions contained within this Request for Proposal.

APPENDIX C. ARIZONA PUBLIC SERVICE BIOENERGY REQUEST FOR PROPOSALS

2018 request for proposal – forest bioenergy resources

registration is open until August 1, 2018 at 5pm MST

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.

Important Dates:

May 7, 2018: RFP issued
August 1, 2018: RFP Registration Deadline & Confidentiality Agreements Due
August 17, 2018: RFP Proposals and associated Proposal fees Due
September 21, 2018: Shortlisted Respondents Notified
October 12, 2018: Final Selection
December 14, 2018: RFP complete

APS will use the PowerAdvocate platform for this RFP and will regularly update the platform to include necessary documents and timely instructions for respondents. To register on Power Advocate please use the link below:

register with PowerAdvocate