WOOD WASTE UTILIZATION ASSESSMENT FOR THE GREATER TAOS, NEW MEXICO REGION

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Final Report

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ABBREVIATIONS

BDT	Bone Dry Ton
BLM	Bureau of Land Management
Btu	British Thermal Unit
CCF	Hundred cubic feet
DBH	Diameter breast height
EPA	US Environmental Protection Agency
FIR-BBER	Forest Industry Research, Bureau of Business and Economic Research
LRS	Landscape Restoration Strategy
MBF	Thousand board feet
MW	Megawatt
NGO’s	Non-Governmental Organizations
PAD-US	Protected Area Database of the United States
PJ	Pinyon and juniper woodlands
SAF	Society of American Foresters
SRM	Society for Range Management
TNC	The Nature Conservancy
TSA	Target Study Area
TSS	TSS Consultants
TSV	Taos Ski Valley
TVWC	Taos Valley Watershed Coalition
USFS	US Forest Service
WPC	Wood Plastic Composites

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INTRODUCTION

The Nature Conservancy (TNC) is coordinating with the Taos Valley Watershed Coalition (TVWC) to support planning and implementation of landscape-scale forest restoration projects across 280,000 acres on the west slope of the Sangre de Cristo Mountains. The Carson National Forest, Taos Pueblo, and numerous private landowners in the region are expected to participate in restoration planning and treatment implementation in the coming years using the TVWC Landscape Restoration Strategy as a guide.

In 2015, the TVWC Landscape Restoration Strategy (LRS) was created as a guiding document that agencies, communities, tribes, Firewise communities, private landowners and non-governmental organizations (NGO's) will implement to protect, improve and restore water quality, quantity and ecological function of forests and streams in the Rio Grande watershed within Taos County. The LRS advocates a blend of treatment activities including controlled burns, natural fire ignitions and thinning activities. Thinning treatments (where appropriate) have the potential to generate forest biomass material as a byproduct. Commercial roundwood is removed as sawlogs, firewood, vigas, and latillas, with residuals (limbs, tops, small stems) piled and burned or chipped and scattered. These residues have the potential to be utilized as feedstock for value-added processes.

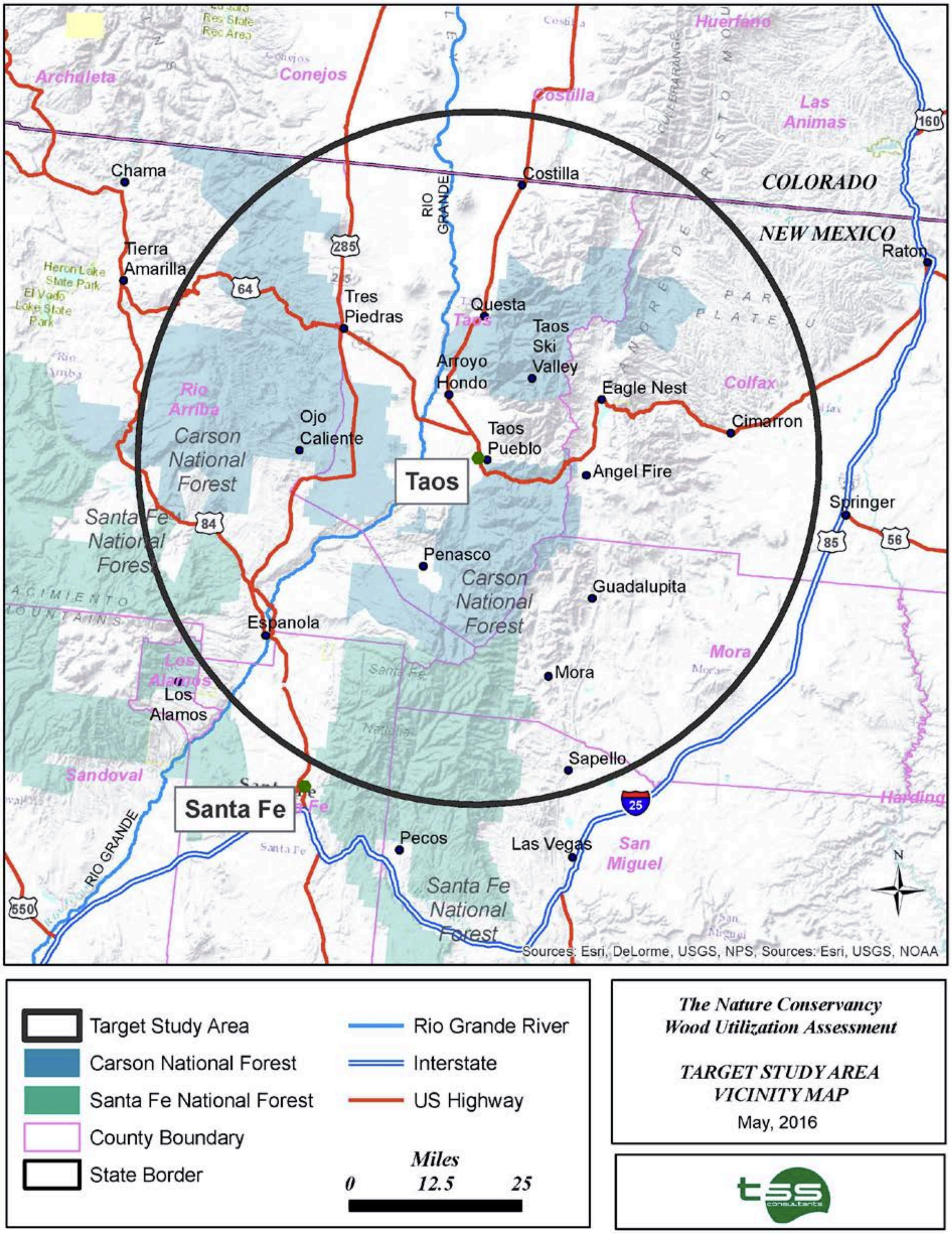
TNC has asked that TSS Consultants (TSS) determine biomass value-added processes that could utilize forest and woodland restoration byproducts generated as a result of the LRS implementation. This would be a Phase I analysis effort, with Phase II (if undertaken) being a detailed feasibility assessment of selected value-added technologies.

Target Study Area

A target study area (TSA) was defined with significant input from TNC staff and the project technical advisory committee. A TSA extending in a 50-mile radius from Taos was selected (Figure 1.). This represents a region in which all of the TSA is within transport distances up to 1.5 hours of one-way drive time from Taos. The eastern portion of the TSA is not as well serviced by roads but is a grassland area with less opportunity for woody biomass utilization. Although tangential to Santa Fe, the TSA contains no major urban areas and is still a relatively intact network of private, federal and tribal lands. The TSA takes in two USDA Forest Service (USFS) national forests, Bureau of Land Management (BLM) rangelands, Pueblo lands, lands managed by the State of New Mexico and privately owned forests and rangeland. It includes all of Taos County and portions of Rio Arriba, Colfax, Mora, Santa Fe and San Miguel counties.

The TSA has several distinct cultural and geographic features. It is bisected by the Rio Grande River and is located just south of the Rio Grande headwaters arising from the San Juan Mountains of southern Colorado. The area is a significant source of water supply in northern New Mexico and into the Rio Grande River. The region has a rich heritage of Spanish Land Grants and Native American peoples. Pueblos are scattered along the Rio Grande corridor. Taos Pueblo and the village of Taos sit side-by-side at the center of the TSA. Land ownership and vegetation cover type characterization for the TSA are addressed in the following sections.

Figure 1. TSA and Vicinity



KEY FINDINGS

Biomass Supply Availability

Findings from the biomass supply availability assessment are summarized in Table 1. The potentially available volume is the total amount of biomass estimated to be produced and considered potentially available annually. It is worth noting that for the forest-sourced analysis, this is not a potential amount based on standing inventory in national forests or on private lands. This represents the amount that is actually being produced or could be produced (if a market for excess biomass existed) on public and private lands that is analyzed to estimate future availability on an annual basis.

Technically available material considers physical constraints such as terrain (steep slopes), transport (road systems that do not support removal), or policy constraints (environmental regulation, wilderness).

Economical biomass is the amount available considering existing competition for the wood waste. It is important to note that economically available biomass in this report is not an analysis of costs and profitability. Rather it is the amount of biomass that is available considering other biomass users and industries that source biomass from within the TSA.

Table 1. Biomass Supply Availability Findings

SOURCE	POTENTIALLY AVAILABLE (BDT/YEAR)	TECHNICALLY AVAILABLE (BDT/YEAR)	ECONOMICALLY AVAILABLE (BDT/YEAR)
Timber Harvest Residuals	6,085	3,189	3,189
Forest Restoration and Fuel Treatment Residuals	34,095	17,878	17,878
Pinyon Juniper Treatment Residuals	10,905	5,761	5,761
Forest Products Manufacturing Residuals	0	0	0
Electric Transmission/Distribution	0	0	0
Construction and Demolition Wood Waste	1,591	1,034	1,034
Residential Tree Trimming	45	36	14
TOTAL	**52,721**	**27,897**	**27,876**

Delivered Cost Forecast

TSS relied on discussions with forest biomass contractors operating in the region, in addition to TSS's past experience, to analyze these costs. Table 2 provides results of the cost review.

Table 2. Biomass Feedstock Collection, Processing, and Transportation Costs

SOURCE	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)	AVERAGE DELIVERED COST ($/BDT)
Timber Harvest Residuals	$41.25	$43.75	$42.50
Forest Restoration and Fuel Treatment Residuals	$46.25	$50.00	$48.13
Pinyon Juniper Treatment Residuals	$47.50	$51.25	$49.38
Urban Wood Waste	$36.25	$41.25	$38.75

Value-Added Opportunities Analysis

Using findings from the biomass feedstock supply availability analysis, field visits in the Taos area, interviews with existing wood products and waste facilities, and potential new wood products developers, TSS conducted a value-added opportunity analysis to assess the range of commercial utilization options available. The emphasis of this analysis is focused on utilization of feedstocks deemed available over and above feedstock types and volumes used by existing commercial enterprises sourcing feedstocks from within the TSA. Thus, the biomass feedstock to be principally considered in the value-added opportunities analysis is that biomass waste material that would be derived from forest hazardous fuels reduction, timber harvest operations and forest restoration activities.

Recommendations and Next Steps

Value-Added Opportunities

In coordination with TNC, TSS identified six potential value-added options for the Taos region. These six options are discussed in further detail below in this report. As part of the TSS scope of work, three of these options are considered candidates for Phase II analysis. These are:

- Wood/plastic composite board
- Biomass heating of a large facility
- Fuel bricks

Both of these options and their potential implementation in the Taos region will benefit from a Phase II analysis. That analysis will take a “deep-dive” into the economic and technical feasibility of these two options.

Community Outreach

In the course of this investigation, TSS worked in concert with TNC to conduct two community workshops in Taos. The initial workshop, held June 8, provided interested community members and stakeholders with an overview of the Rio Grande Water Fund objectives and an overview of the wood waste feedstock utilization assessment. The second workshop, held August 25, provided an opportunity for TSS and TNC to review initial feedstock supply findings and discuss the range of value-added utilization options. Notes for both meetings can be found in the Appendix.

TSS recommends that continued dialogue with the community is critical to success. Local businesses, residents, land managers and agency staff should have the opportunity to weigh in on the value-added technologies targeted for possible deployment. As this report is finalized, an executive summary document should be posted on the TNC New Mexico website.

Fuels Treatment/Restoration Demonstrations

Forest and rangeland restoration activities now conducted within the greater Taos region are typically conducted using hand crews, with most of the woody biomass produced left on site. If an active forest biomass utilization sector were to be established in the region, a vibrant supply chain would need to be developed. TSS recommends consideration of a series of fuels treatment/restoration trials that would facilitate demonstration of the latest harvest, collection, processing and transport technologies. These demonstrations would allow local land managers and contractors to view conventional and innovative equipment up close. Site conditions, pre and post treatment, could be monitored to analyze site impacts (e.g., soils, vegetation, fire behavior) and cost effectiveness/efficiency.

ENVIRONMENTAL SETTING

Woody biomass availability for any given region is dependent on vegetation cover and topography, and on land ownership and management objectives. Initial assessment for the TSA characterizes these important factors.

Vegetation Cover

Vegetation cover types for the TSA were mapped and acreages were calculated using US Geological Survey LANDFIRE 2012 datasets.[1] LANDFIRE existing vegetation (EVT) describes species composition currently present. LANDFIRE vegetation data utilizes USGS GAP Analysis Program vegetation classifications and includes crosswalks for Society of American Foresters (SAF) and Society for Range Management (SRM) vegetation cover classes.[2]

Major vegetation cover type classes in the TSA are shown in Table 3 including their acreage within the TSA boundary. Vegetation type subclasses were listed to provide additional information on the class but only included when they constitute a significant component of the vegetation type. Therefore the vegetation type subclasses in Table 3 do not necessarily sum to the total acreage in the vegetation class.

Conifer ecosystems occur on over half of the TSA, with approximately 1.85 million acres of conifer forests and 730,000 acres of pinyon-juniper woodlands. Conifer forest types follow an elevation gradient that is typical of the southern Rocky Mountains; spruce-fir forests occur at high elevations, mixed conifer with Douglas fir is found at mid-elevations, and ponderosa pine forest or woodland occurs at lower elevations. The spruce-fir vegetation type is both Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Mesic Montane Mixed Conifer Forest that intergrades with the spruce-fir type. Although Southern Rocky Mountain Ponderosa Pine Woodland is dominant in its vegetation type, limber pine and lodgepole pine also occur. Pinyon-juniper woodlands are situated at lower elevations than, and often intergrade with, ponderosa pine woodlands. The aspen class, which is typically found at higher elevations, includes both Rocky Mountain Aspen Forest and Inter-Mountain Basins Aspen-Mixed Conifer Forest.

The shrubland vegetation type has a large subclass component of sagebrush, mostly Inter-Mountain Basins Big Sagebrush Shrubland or Semi -Desert Shrub-Steppe. The desert scrub subclass is predominantly Inter-Mountain Basins Mixed Salt Desert Scrub and the shrublands subclass is mostly Rocky Mountain Lower Montane-Foothill Shrubland and Inter-Mountain Basins Greasewood Flat. Grasslands are dominant in the eastern portion of the TSA and are mostly Western Great Plains Shortgrass Prairie. Riparian areas occupy an important but relatively small area within the TSA, and there is almost no open water. The developed class includes urban areas but also low-density development in rural areas; developed class accounts for the acreage in roads. The major vegetation cover classes shown in Table 3 are mapped in

[1] USGS LANDFIRE: http://www.landfire.gov/index.php

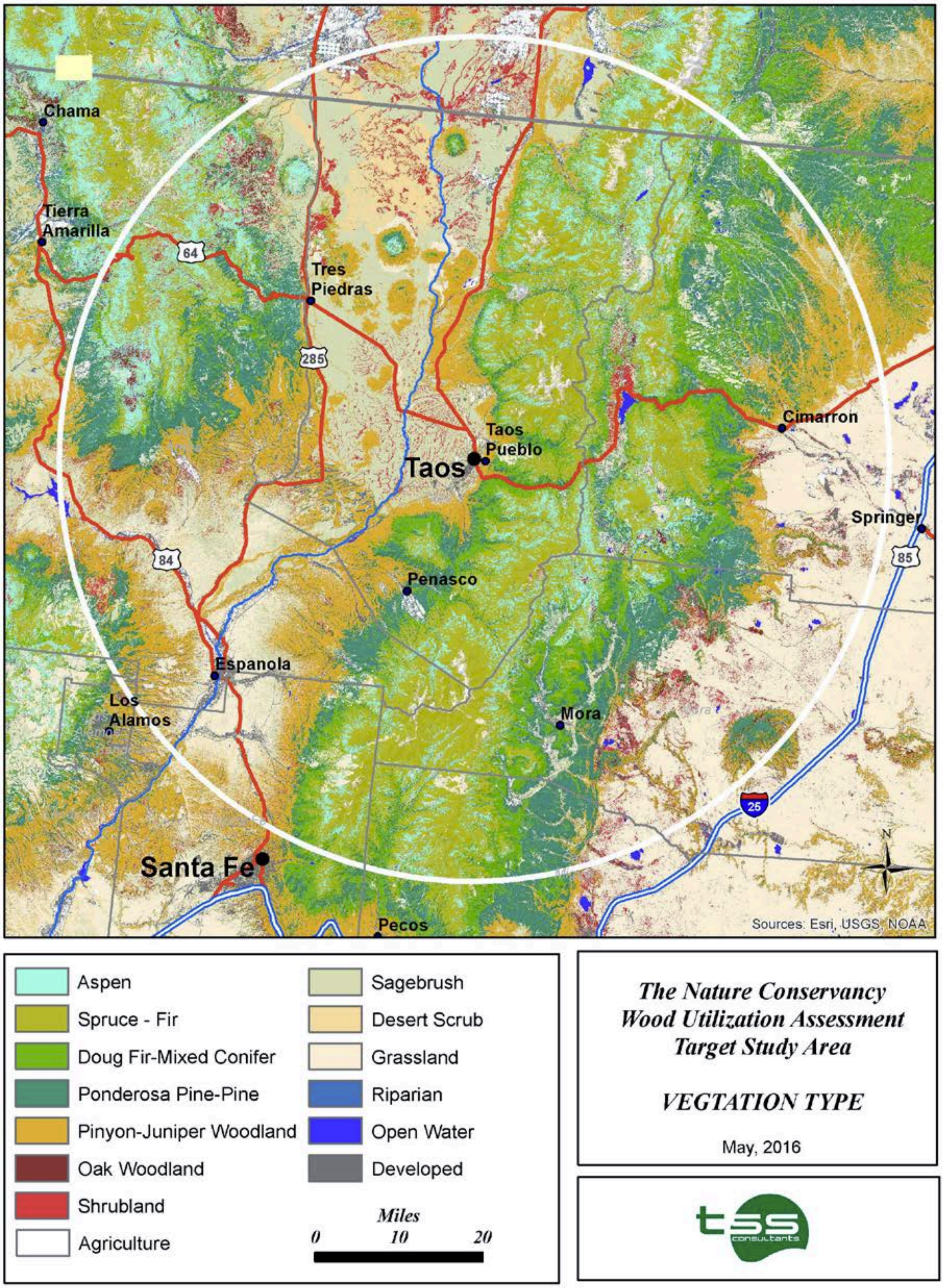
[2] Vegetation units were originally based on NatureServe's Ecological Systems Classification and the National Land Cover Database life form types. Later, USGS GAP analysis class names were added. LANDFIRE data products are created at a 30-meter grid spatial resolution.

Figure 2. Vegetation type subclasses are listed only if they form a significant component of the vegetation type. Every subclass is not listed and therefore, subclasses do not necessarily sum to the total acreage in the vegetation class.

Table 3. Vegetation Cover Type with Acreages

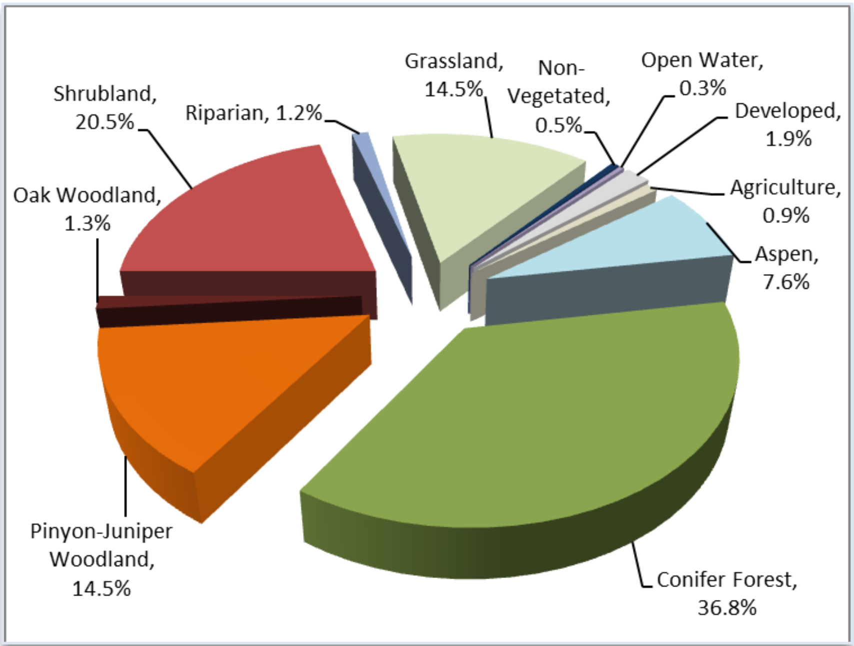
VEGETATION TYPE		TSA		
		ACRES	ACRES*	PERCENT IN TSA
Agriculture		**44,816**		**0.9%**
Aspen		**383,321**		**7.6%**
	Aspen-Mixed Conifer Forest		*268,840*	
	Rocky Mountain Aspen Forest		*114,481*	
Conifer Forest		**1,848,248**		**36.8%**
	Spruce-Fir Forest		*832,047*	
	Ponderosa Pine and other Pine Forest and Woodlands		*624,411*	
	Montane Mixed Conifer-Douglas Fir Forest		*391,791*	
Pinyon-Juniper Woodland		**730,441**		**14.5%**
	Colorado Plateau Pinyon-Juniper Woodland		*450,589*	
	Southern Rocky Mountain Pinyon-Juniper Woodland		*267,201*	
	Juniper Woodland Savanna		*10,190*	
Oak Woodland		**64,402**		**1.3%**
	Quercus gambelii Alliance		*35,747*	
	Gambel Oak-Mixed Montane Shrubland		*27,791*	
Shrublands		**1,030,053**		**20.5%**
	Shrubland		*166,675*	
	Sagebrush		*739,017*	
	Desert Scrub		*124,360*	
Riparian		**59,562**		**1.2%**
Grassland		**726,878**		**14.5%**
	Western Great Plains Shortgrass Prairie		*401,837*	
	Chihuahuan Sandy Plains Semi-Desert Grassland		*141,696*	
	Southern Rocky Mountain Montane-Subalpine Grassland		*59,919*	
Sparseley or Non-Vegetated		**27,564**		**0.5%**
Open Water		**17,275**		**0.3%**
Developed		**93,511**		1.9%
TOTAL		**5,026,071**		**100%**

Figure 2. Vegetation Cover Type Map



Distribution of the vegetation types listed in Table 3 are shown in Figure 3. The distribution chart shows that vegetation types with the potential to produce woody biomass occur on approximately 51.0% of the TSA: conifer forest on 36.8 % and pinyon-juniper woodland on 14.5%. Note that the 51% figure (just over 2.5 million acres) is quite important as this represents the landscape that could produce woody biomass material long term. About 20% of the TSA consists of shrublands and 14.5% is grasslands.

Figure 3. Vegetation Cover Type Distribution



Land Ownership

Land ownership is important as a driver of vegetation management objectives and therefore the potential supply of biomass feedstock. The fundamental driver of regional biomass long-term supply is the ownership and management of key vegetation types, specifically conifer forest and pinyon-juniper woodland. Ownership of the landscapes capable of producing biomass is discussed in the following section (Ownership and Vegetation Type). Ownership of landscapes capable of producing biomass is critical to the long-term sustainable availability of feedstock. Ownership and management jurisdiction directly impact policy, regulations, and management with regard to vegetation treatment activities. Within forest and woodland ecosystems, the level of management activity is typically higher and operational limitations are less restrictive on privately-managed lands. Federal land administration is focused on multiple objectives (e.g., recreation, habitat, fire resiliency) that significantly influence vegetation management and dictate woody biomass availability and quantity. For example, only about one-third of the 50-mile radius TSA is classified as conifer forest (Table 3), and the ownership and management objectives of these acres are critical for biomass supply (shown in following section, Table 4).

Table 4 summarizes land ownership with acreage in the TSA and Figure 4 maps the major landowner categories. Land ownership of small acreages was not mapped because small acreages are not visible at the scale of the entire TSA**.** The ownership analysis was prepared from spatial data obtained from multiple sources and compiled into an ownership database for the TSA. Ownership sources include the US Forest Service (USFS),[3] the Bureau of Land Management (BLM),[4] and the Protected Area Database of the US (PAD-US).[5] TNC provided an updated GIS file of the PAD-US database with correct wilderness areas identified.[6]

There are over 5.0 million acres within the TSA The single largest land ownership class is private lands with over 2.2 million acres. Large commercial ranch holdings make up a large portion of the private land with over half a million acres located within the TSA.

The three major public entity landowners combined manage 2,546,515 acres, making up approximately half of the TSA (USFS 1,779,144 acres, BLM 533,634 acres, and State of New Mexico, 233,737 acres). The USFS manages two national forests that fall within the TSA, the Carson and the Santa Fe National Forests. The Carson is the larger with a total of 1,109,302 acres. The State of New Mexico has state trust lands managed by the State Land Office (158,502 acres) and lands managed by departments of state government, NM Energy, Minerals and Natural Resources and the NM Department of Game and Fish (75,235 acres).

National forest boundaries have complex land ownership patterns containing both federal lands, owned and managed by the USFS, and private lands, owned or managed by private landowners. For lands located within a national forest administrative boundary, acreages for federal and private ownership were kept separate for analyses in this report.[7]

There are eight pueblos which fall either all or in part within the TSA boundary (263,628 acres). The pueblos are listed individually in (Table 4).

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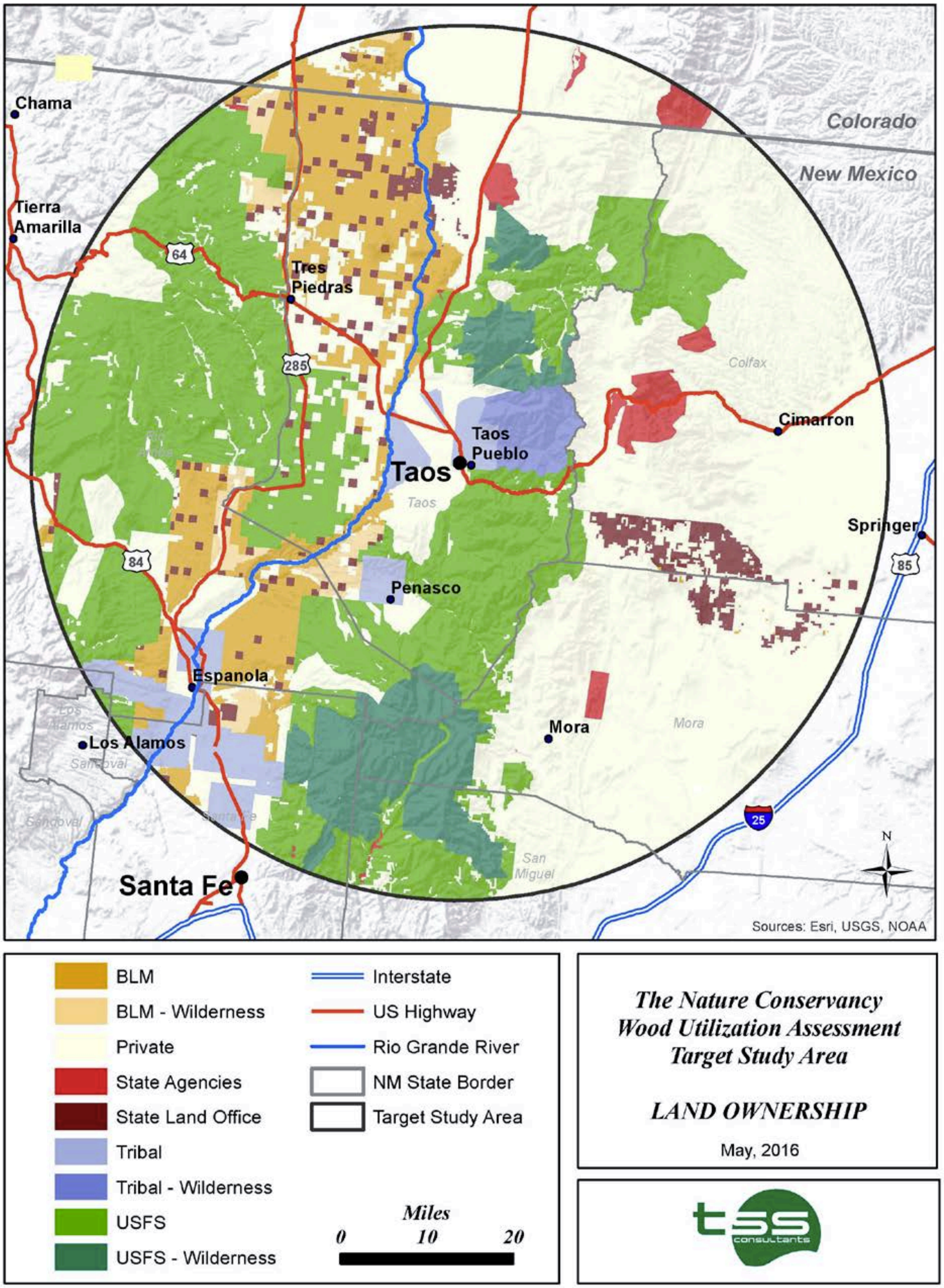
[3] US Forest Service Region 3 Geospatial data; http://www.fs.usda.gov/detail/r3/landmanagement/gis/?cid=stelprdb5202474
[4] Bureau of Land Management New Mexico Spatial Data: http://www.blm.gov/nm/st/en/prog/more/geographic_sciences/spatial_data_metadata.html
[5] PAD-US; gapanalysis.usgs.gov/padus
[6] Personal Communication, Steven Bassett, TNC.
[7] USFS ownership always refers to those lands owned and managed by the Forest Service, not private lands within national forest boundaries.

Table 4. Land Ownership with Acreages

OWNERSHIP TYPE		TSA		
		ACRES	ACRES	PERCENT IN TSA*
US Forest Service (Non Wilderness)		**1,491,165**		29.7%
	Carson National Forest		*1,039,230*	
	Santa Fe National Forest		*314,059*	
	Other USFS Non Wilderness		*137,876*	
US Forest Service Wilderness		**287,979**		5.7%
	Pecos Wilderness- mostly in Santa Fe NF		*217,906*	
	Other USFS Wilderness – in Carson NF		*70,072*	
Bureau of Land Management (Non Wilderness)		**460,828**		9.2%
	BLM Public Land		*127,326*	
	BLM Recreation Areas		*333,502*	
Bureau of Land Management Wilderness		**72,806**		1.4%
National Park Service		**721**		<0.1%
State of New Mexico		**233,737**		4.7%
	State Land Office		*158,502*	
	NM Dept. Game and Fish, NM Energy, Minerals and Natural Resources Dept.		*75,235*	
Native American**		**209,394**		4.2%
	Nambe Pueblo		*20,479*	
	Picuris Pueblo		*17,315*	
	Pueblo of Pojoaque		*13,485*	
	Pueblo of San Ildefonso		*30,119*	
	Ohkay Owingeh		*17,109*	
	Santa Clara Pueblo		*49,793*	
	Pueblo of Tesuque		*16,858*	
	Taos Pueblo		*44,235*	
Native American Wilderness		**54,234**		1.1%
	Taos Pueblo Blue Lake Wilderness		*54,234*	
Department of Defense		**11,626**		0.2%
Private		**2,203,600**		43.8%
TOTAL ACRES IN THE TSA		**5,026,090**		**100%**

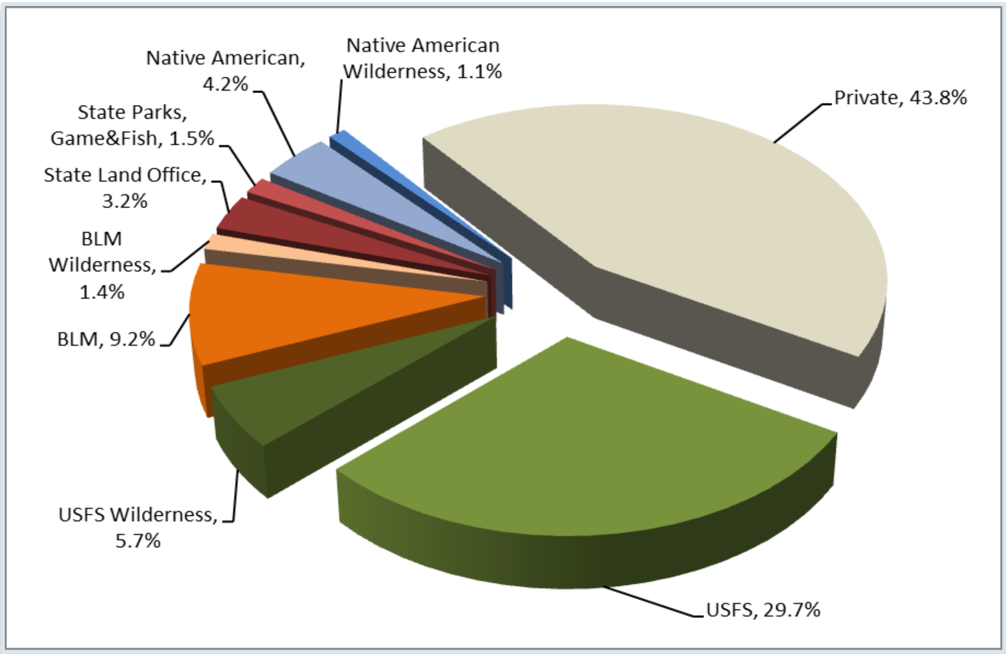
*Percent is calculated as percent of total TSA acres that are owned by the listed entity.
**Acreages of Native American land were taken from the PAD-US database and may or may not be in agreement with land holding assessment by the tribal government. Tribal government records are in all cases considered correct. The acreage assessments presented are adequate for the goal of this report.

Figure 4. Land Ownership Map



Land ownership distribution is shown in Figure 5 using the major landowner categories and acreages in Table 4.

Figure 5. Land Ownership Distribution



Exclusions are lands within the TSA which would be excluded from vegetation treatment activities that create woody biomass and allow its removal. Designated wilderness areas are exclusions and wilderness held by the USFS, BLM and Taos Pueblo are listed separately in Table 4. Wilderness totals 415,020 acres, 8.2% of the TSA (Figure 5). Other land ownership categories may, but do not necessarily, exclude vegetation treatment activities that produce biomass. For example, NM Department of Game and Fish wildlife management areas could possibly exclude treatments, or Native American governments may not permit biomass removal on some lands. However, due to the extensive need for forest and woodland restoration, these ownerships need to be examined on a case-by-case basis and cannot be categorically considered exclusions.

Land Ownership and Vegetation Type

Table 5 and Table 6 summarize land ownership for the vegetation types most likely to generate suitable forest biomass: conifer forest, pinyon-juniper woodland, aspen forest and oak woodland. Only non-wilderness was included in the table. The USFS, 37.8%, and private landowners, 41.7%, manage significant tracts of conifer forest within the TSA. The majority of pinyon-juniper woodlands, 45.4%, are owned by private landowners, although 29.0% are under USFS jurisdiction and 13.9% are under BLM jurisdiction. Private landowners own slightly more acreage of all vegetation types of interest (potential sources of woody biomass), about 1.3 million acres, than the US Forest Service, with about 1.1 million acres.

Table 5. Vegetation Type by Public Ownership

VEGETATION TYPE	USFS NON WILDERNESS		NM STATE LAND OFFICE		BLM NON WILDERNESS	
	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT
Conifer Forest	699,225	37.8%	40,429	2.2%	10,472	0.6%
Pinyon-Juniper Woodland	212,155	29.0%	19,692	2.7%	99,492	13.6%
Aspen Forest	181,584	47.4%	5,893	1.5%	2,120	0.6%
Oak Woodland	24,421	37.9%	1,341	2.1%	1,015	1.6%
TOTAL	**1,117,386**		**67,355**		**113,099**	

Table 6. Vegetation Type by Private and Pueblo Ownership

VEGETATION TYPE	PRIVATE		PUEBLO NON WILDERNESS	
	ACRES	PERCENT	ACRES	PERCENT
Conifer Forest	770,241	41.7%	14,824	0.8%
Pinyon-Juniper Woodland	331,496	45.4%	41,716	5.7%
Aspen Forest	141,872	37.0%	800	0.2%
Oak Woodland	35,481	55.1%	404	0.6%
TOTAL	**1,279,091**		**57,744**	

Note that the percent figures included in Table 5 and Table 6 represent the amount of vegetation type acreage owned by each ownership class as a percent of the total vegetation type acreage in the TSA as shown in Table 4.

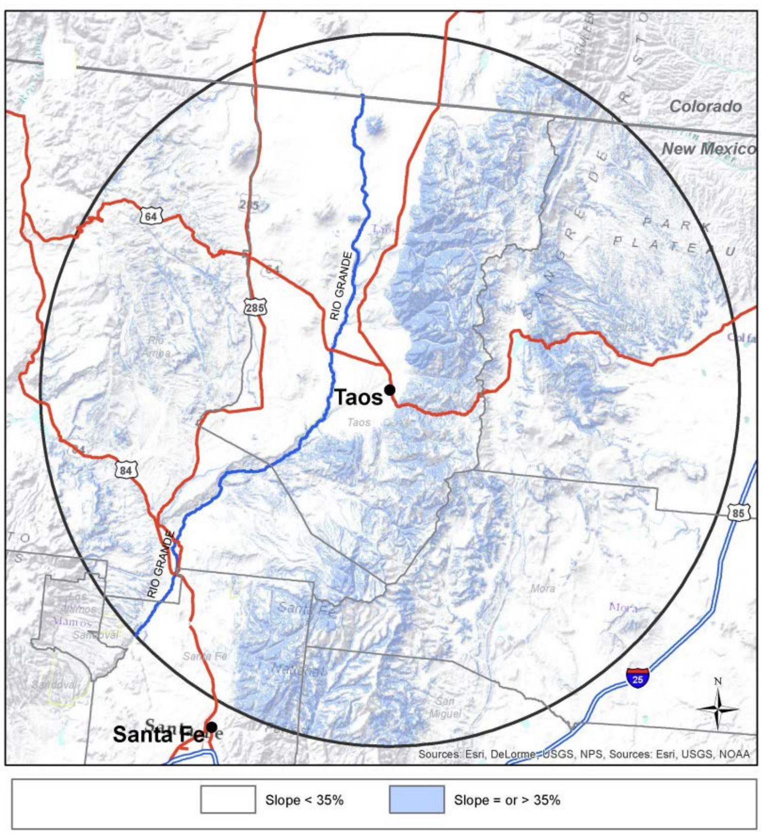
Topography

Forest biomass collection activities are generally restricted to topography that will allow ready access for equipment and crew. Steep topography over 35% slope gradient is considered to be the breakoff point for ground-based logging and/or biomass recovery equipment on federally managed lands (USFS and BLM). Recent field trials on the Kaibab National Forest (Arizona) have demonstrated the potential viability of utilizing mechanical equipment on steep slopes and the relatively low impacts to soil resources.[8] Some national forests are considering modifying forest plans to allow mechanical equipment to operate on steeper terrain (40% plus).[9] Private land managers may use ground-based equipment on slopes up to 50%, but the cost of operating on sustained slopes above 35% are quite high and often considered prohibitive.

Areas with 35% slope or higher are mapped in Figure 6 (steep slope is shown in blue). The TSA is characterized by mountainous and rough terrain. Over the entire TSA, approximately 17.5% of the area has slopes greater than 35% slope gradient.

Table 7 summarizes the results of the slope gradient analysis specifically for conifer forest and juniper woodland landscapes. Approximately 30.6% of conifer forests and 15.8% of pinyon-juniper woodlands occur on land steeper than 35% slope.

Figure 6. Slope Gradient Greater Than 35%



[8] Per discussions with Bob Rich, USFS Forest Operations Specialist for Region 3.
[9] Ibid.

Table 7. Slope Assessment for Conifer Forest and Pinyon-Juniper Woodlands

COVER CATEGORY	PERCENT	
	< 35% SLOPE	> 35% SLOPE
Conifer Forest	69.4%	30.6%
Pinyon-Juniper Woodland	84.2%	15.8%
WEIGHTED AVERAGE	73.6%	26.4%

BIOMASS FEEDSTOCK SUPPLY ANALYSIS

Feedstock considered in this analysis includes forest or woodland sourced material and forest products manufacturing residuals (referred to as forest sourced) and urban wood waste (referred to as urban sourced). For all biomass sources, TSS has estimated a potentially, technically and economically available volume.

Methodology

The potentially available volume is the total amount of biomass estimated to be produced annually. It is worth noting that for the forest-sourced analysis, this is not a potential amount based on standing inventory in national forests or on private lands. Rather it is the amount that is actually being produced or could be produced (if a market for excess biomass existed) on public and private lands that is analyzed to estimate future availability on an annual basis.

Recoverable biomass is judged to be technically available considering physical constraints such as terrain (steep slopes), transport (road systems that do not support removal) or policy constraints (environmental regulation, wilderness). For example, not all road systems will accommodate biomass recovery operations and access by harvest equipment or biomass transport by chip vans. Slope gradient has a significant impact on both forest road layout and on the ability to perform harvest operations.

Economical biomass is the amount available considering existing competition for the wood waste material. It is important to note that economically available biomass in this report is not an analysis of costs and profitability. Rather it is the amount of biomass that is available considering other biomass users and industries that source biomass from within the TSA.

Forest-Sourced Biomass

<u>Timber Harvest Residuals</u>

Timber harvest residuals can provide significant volumes of woody biomass material. Typically available as limbs, tops and unmerchantable logs,[10] these residuals are byproducts of commercial timber harvest operations. As such, residuals have very limited market value though they can be a relatively economic raw material feedstock source for end uses such as soil amendment (e.g., compost), or bioenergy production (e.g., power or thermal energy). In addition, top wood can be utilized as chip logs if the pulp/paper market values support the additional costs to delimb, load and transport.

Timber harvest activity on USFS land is reported by the USFS in Cut and Sold Reports.[11] Cut and Sold reports show total volumes and values of all convertible forest products sold and harvested from the National Forest System lands. The data is made available quarterly and annually for every national forest. Cut volumes are reported in hundred cubic feet (CCF) and thousand board feet (MBF).[12] A review of the 2011 through 2015 cut and sold data was

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[10] Unmerchantable logs are typically too small or defective (diseased or dead) for manufacturing into lumber.
[11] USFS Forest Products, Cut and Sold Reports: http://www.fs.fed.us/forestmanagement/products/sold-harvest/cut-sold.shtml
[12] MBF = thousand board foot measure. One board foot is nominally 12” long by 12” wide and 1” thick.

conducted to quantify previous timber harvest activities within the TSA. Table 8 shows results for timber harvested on the Carson and Santa Fe National Forests for a five-year period from FY 2011 to FY 2015 expressed in MBF per year. Note that Table 8 shows harvest volume for the entire forest; Table 9 shows harvest volume estimates reflecting the acreage of national forest located within the TSA.

Table 8. USFS Cut and Sold Reports Timber Harvest Volume

FOREST OUTPUT	FY2011 (MBF/YR)	FY2012 (MBF/YR)	FY2013 (MBF/YR)	FY2014 (MBF/YR)	FY2015 (MBF/YR)	AVERAGE (MBF/YR)
Carson National Forest						
Sawtimber	482	804	270	334	274	433
Pulpwood	0	0	0	0	0	0
Poles	647	1,183	903	490	350	715
TOTAL	**1,129**	**1,987**	**1,173**	**824**	**624**	**1,147**
Santa Fe National Forest						
Sawtimber	332	776	777	925	743	711
Pulpwood	107	8	136	78	0	66
Poles	1,274	1,118	8	1,442	1,254	1,019
TOTAL	**1,713**	**1,902**	**921**	**2,445**	**1,997**	**1,796**

Utilization specifications in Region 3 identify sawtimber as trees greater than 9 inches DBH.[13] Pulpwood is made up of trees from 5 to 9 inches DBH. Poles are typically sold for utility lines; however, in northern New Mexico, these smaller stems (typically 5 to 11 inches DBH) may also be sold for use as vigas[14] or latillas[15] in home building or fencing. Poles vary in size but are not smaller than 9 inches DBH and follow the same utilization specifications as sawtimber.

Estimating timber harvest volume within the TSA requires apportioning the forest level data to reflect the amount of forest located within the TSA boundary. Geographic Information System (GIS) analysis is used to calculate these acreages. About 83% of the Carson National Forest and about 27% of the Santa Fe National Forest lies within the TSA. Data from the previous 5-year period provide an estimate of anticipated timber harvest in the near future. However, discussions with the Carson National Forest staff showed that a new five-year management plan would increase timber harvest for the next five years compared to the recent past. Therefore, timber harvest volume shown in Table 9 is estimated using average timber harvest volume (Table 8), adjusted upward based on the five-year plan of work on the Carson National Forest,[16] and the percent of the national forest within the TSA.

Forest Industry Research, Bureau of Business and Economic Research (FIR-BBER), University of Montana assisted TSS with applying a logging residuals factor for commercial timber harvests

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[13] DBH = diameter at breast height.
[14] Viga is a rough-hewn beam typically used in home construction to support a roof or ceiling.
[15] Latilla is a small rough-hewn stick used as a traditional ceiling material laid between beam or vigas.
[16] Provided by Gabriel Romero, East Zone Silviculturist and Jonathan Romero, Fuels Forester.

in the ponderosa pine and Douglas fir - mixed conifer stands found in the TSA.[17] The estimate for green tons (GT) of logging residue produced by commercial harvesting operations was made using both the Timber Products Output (TPO) database and current field data from a logging utilization study in northern New Mexico.[18] (It does not include non-commercial thinning, fuels reduction, or other treatments removing small diameter (DBH <5") material.) The FIR-BBER analysis indicates approximately 1.57 GT, or approximately 0.8 BDT, of residue are generated for every MBF of harvest in the north central region of NM.[19] Table 9 applies this woody biomass residue factor to the timber harvest volume estimates and calculates potentially available timber harvest residuals in BDT/year.

Table 9. USFS Timber Harvest Volume and Residuals in the TSA

NATIONAL FOREST	PERCENT IN TSA	TIMBER HARVEST AVERAGE (MBF/YEAR)	TIMBER HARVEST RESIDUALS (BDT/YEAR)
Carson	82.7%	5,280	4,224
Santa Fe	27.6%	496	397
TOTAL		**5,776**	**4,621**

Private lands located within the TSA that actively manage forest landscapes and harvest sawlogs, firewood and vigas/latillas are primarily privately held ranches. Land managers for six of the largest ranches[20] were interviewed by TSS for this assessment, and all confirmed that resource management objectives included a focus on wildlife habitat, recreation (e.g., hunting) and livestock. Vegetation management is conducted to reduce the threat of catastrophic wildfire and as a pre-treatment for prescribed fire. Revenue from the sale of sawlogs, viga/latillas and firewood is relatively meager due to long transport distances and limited market value that typically only covers the cost of treatment. Table 10 summarizes results of TSS interviews with private land managers regarding timber harvest plans for the next five years. Not all privately managed properties with commercial sawtimber within the TSA are held by ranches. Other private ownerships category is included in Table 10 to represent other, typically small private holdings.

Table 10. Private Land Timber Harvest Volume and Residuals in the TSA

LANDOWNER	TIMBER HARVEST AVERAGE (MBF/YEAR)	TIMBER HARVEST RESIDUALS (BDT/YEAR)
Area Ranches	1,580	1,264
Other Private Ownerships	250	200
TOTAL	**1,830**	**1,464**

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[17] Forest Research Institute, http://www.bber.umt.edu/FIR/Default.asp, and personal communication and report prepared by Eric Simmons.
[18] Ibid and "Logging Utilization in New Mexico" Sacramento Mountain Wood Industry Summit presentation by Eric Simmons.
[19] Logging residues in north central NM are slightly lower than the state level estimate of 1.76 GT/MBF.
[20] Bobcat Ranch, Express UU Bar Ranch, Philmont Ranch, CS Ranch, Vermejo Ranch, and Rio Castilla Livestock Cooperative.

For all biomass sources, TSS has estimated potentially, technically and economically available volumes. The potentially available volume is the total amount of biomass estimated to be produced and available annually without restrictions. However, because of limitations due to slope gradient and road conditions that impact the ability to gather, process, or transport all that is produced, TSS adjusts for recovery using a recovery factor to estimate the volume technically available. Economically available biomass accounts for current competition (which is basically non-existent within the TSA). Not all road systems will accommodate biomass recovery operations. Slope gradient has a significant impact on forest road layout.

Slope gradient analysis (see Table7) confirms that approximately 69% of conifer forest is located on slopes less than 35% gradient. Interviews with USFS foresters and ranch managers confirmed that slope conditions and road systems can be a limiting factor. While the use of conventional 40-foot chip vans is the most economical form of transport, there are short chip vans or modified chip vans[21] and short log pulpwood trailers that can be utilized to transport wood chips or top logs. Based on these interviews and the slope gradient analysis, 50% of the timber harvest operations on publicly managed forestlands and 60% of operations on private forests are located on road systems that will support biomass feedstock transport using both conventional and alternative chip vans.

Table 11 shows the timber harvest residuals considered potentially, technically and economically available on an annual basis. Approximately 3,189 BDT per year of timber harvest residuals are considered economically available.

Table 11. Total Timber Harvest Residuals

SOURCE	PRIVATE (BDT/YEAR)	PUBLIC (BDT/YEAR)
Carson National Forest		4,224
Santa Fe National Forest		397
Area Ranches	1,264	
Other Private Landowners	200	
POTENTIALLY AVAILABLE	1,464	4,621
ADJUSTMENT FOR RECOVERY	- 586	- 2,311
TECHNICALLY AVAILABLE	878	2,311
ADJUSTMENT FOR COMPETING USES	0	0
ECONOMICALLY AVAILABLE	878	2,311
TOTAL PRIVATE AND PUBLIC ECONOMICALLY AVAILABLE	**3,189**	

<u>Forest Restoration and Hazardous Fuels Treatment</u>

Due to high fire danger conditions and overstocked forests and landscapes, there are concerted efforts across all forest and woodland (pinyon-juniper dominated sites) ownerships within the

[21] TSS completed a forest biomass transport assessment using a variety of alternative biomass chip transport technologies. The March 2012 report can be found at: http://tssconsultants.com/reports-papers/

TSA to proactively restore forests to a more healthy condition and reduce hazardous fuels in support of fire resilient ecosystems. One example of a local, coordinated effort is the Taos Valley Watershed Coalition's effort to support planning and implementation of landscape-scale forest restoration projects across 280,000 acres on the west slope of the Sangre de Cristo Mountains. Local land management agencies, tribes and private landowners are expected to participate in restoration planning and treatment implementation in the coming years using the TVWC Landscape Restoration Strategy[22] as a guide. In 2015, the TVWC crafted the LRS as a document that agencies, communities, tribes, Firewise communities, and NGO's plan to implement to protect, improve and restore water quality, quantity and ecological function of forests and streams in the Rio Grande watershed within Taos County. The LRS advocates a blend of treatment activities including controlled burns, natural fire ignitions and forest thinning and is an impressive example of an area-based coalition coordinating fuels reduction techniques and best practices.

Resource managers and landowners are currently conducting forest and woodland thinning activities to achieve fuels treatment and stocking control (reduce the number of stems per acre) within the TSA. As noted earlier, within the ponderosa pine and mixed conifer forest vegetation types, many of the smaller stems (typically 5 to 12" DBH) are utilized as firewood, vigas or latillas, thus leaving limbs and tops potentially available for use as biomass feedstock. On pinyon-juniper dominated woodlands, firewood removal is also the standard utilization for stems removed during fuels treatment. Personal use firewood and commercial firewood operations are a very important consideration within the TSA. Discussions with the mayor of Taos and various land managers confirmed that there is a significant demand for firewood within the TSA. Many of the local residents rely on firewood as a primary or secondary home heating source.

Interviews with resource managers confirmed that most of the limbs and tops are piled and burned as the primary disposal method, either within the treatment unit or roadside. In some sensitive watersheds, these residuals are retained on steeper sites for soil stability.[23] Interviews with private land managers conducting forest restoration and fuels treatment operations confirm a recovery factor of approximately 10 BDT per acre applies for small material (not including small stems utilized as vigas/latillas or firewood) generated during forest thinning operations in ponderosa pine and mixed conifer stands within the TSA. Federal lands have a lower recovery factor of approximately 7 BDT per acre,[24] due to multiple land management objectives and down woody material retention standards. Table 12 shows results for potential feedstock availability from forest restoration and fuels reduction material on both private and public lands. There is a potential availability of 34,095 BDT per year from within the TSA.

As discussed earlier with regards to timber harvest operations, road systems, slope gradient conditions and terrain will define landscapes that are technically available for forest biomass collection and transport. This holds true with fuels reduction activities as well. Using a similar methodology and recovery factors, TSS assumes that 50% of the fuels treatment material on public lands is accessible and 60% of fuels treatment on private, tribal and state lands is accessible and considered technically available. A total of 17,878 BDT per year is technically

[22] https://www.google.com/?gws_rd=ssl#q=Taos+Valley+Watershed+Coalition
[23] Per interview with Gabe Romero, East Zone Silviculturist, Carson National Forest.
[24] Per interview with Gabe Romero, East Zone Silviculturist, and Jonathan Romero, Fuels Forester, Carson National Forest.

available. Adjusting for existing uses (which there are currently none) within the TSA, approximately 17,878 BDT per year are considered economically available.

Table 12. Forest Restoration and Fuels Treatment Activities and Residuals

SOURCE	TREATMENT AREA AVERAGE (ACRES/YEAR)	BIOMASS FEEDSTOCK (BDT/YEAR)
Carson NF - East Zone	1,285	8,995
Carson NF - West Zone	2,200	15,400
Santa Fe NF	200	1,400
Rio Costilla Cooperative Livestock Assoc	15	150
Taos Pueblo	30	300
Angel Fire CWPP and Fire Wise Program	13	125
NRCS[25] Supported Projects	138	1,375
New Mexico Forest Health Improvement Program	200	2,000
Taos Soil and Water Conservation District Supported Projects	25	250
Taos CWPP	35	350
Taos Ski Valley	25	250
NM State Lands	350	3,500
SUBTOTAL	4,315	34,095
POTENTIALLY AVAILABLE	34,095	
ADJUSTMENT FOR RECOVERY	-16,218	
TECHNICALLY AVAILABLE	17,878	
ADJUSTMENT FOR COMPETING USES	0	
ECONOMICALLY AVAILABLE	**17,878**	

Pinyon-Juniper Removal and Hazardous Fuels Reduction

Due to successful wildfire suppression activities in the Southwest, invasive plant species such as pinyon pine and juniper, collectively known as PJ, have proliferated. This plant community typically occurs between 4,500’ and 7,500’ elevation, transitioning from grasslands or shrublands at lower elevations to ponderosa pine at higher elevations. Primarily impacting wildlife habitat and water availability, the presence of PJ in unnaturally high concentrations is a major resource management challenge facing land managers in the west. In recent years, both federal and state agencies have allocated resources (funding and staff) focused on the removal of excessive concentrations of PJ. Currently, the most common treatment technique deployed is cutting and removal of PJ stems (typically for use as firewood) with limbs and tops piled and burned, either within the treatment unit or roadside. Piling and burning of PJ limbs and tops has

[25] Natural Resource Conservation Service.

clear liabilities (potential for wildfire, impacts to wildlife habitat) and issues (air quality, regional haze, contribution to greenhouse gases). In addition, there is some mechanical mastication of PJ dominated landscapes within the TSA. Masticated material left on site is not considered recoverable for value-added utilization.

Interviews with federal land managers conducting PJ woodland restoration and fuels treatment activities confirm potential availability of about 5 BDT per acre applies for small stems (not including firewood material) and limbs/tops generated and typically piled and burned within the TSA. This assumes that some material is left onsite to meet retention standards for down woody material. Private, Tribal and state lands have a higher availability at approximately 7 BDT per acre. Table 13 shows results for potential PJ treatment activity residuals at approximately 10,905 BDT per year from within the TSA.

As discussed earlier with regards to timber harvest and forest fuels treatment, slope gradient conditions and terrain will define landscapes that are technically available for PJ biomass collection and removal. Using a similar methodology and recovery factors, TSS assumes that 50% of the PJ fuels treatment material on public lands is accessible and 80% of fuels treatment on private, Tribal and state lands is accessible and considered technically available. A total of 5,761 BDT per year is technically available. Adjusting for existing uses (which there are currently none) within the TSA, approximately 5,761 BDT per year are considered economically available.

Table 13. Pinyon-Juniper Treatment and Fuels Reduction Activities

SOURCE	TREATMENT AREA AVERAGE (ACRES/YEAR)	BIOMASS FEEDSTOCK (BDT/YEAR)
Carson NF - East Zone	325	1,625
Carson NF - West Zone	640	3,200
Santa Fe NF	200	1,000
BLM - Taos District	400	2,000
Area Ranches	125	875
Taos Pueblo	15	105
NM State Lands	150	1,050
NRCS Supported Projects	150	1,050
SUBTOTAL	2,005	10,905
POTENTIALLY AVAILABLE	10,905	
ADJUSTMENT FOR RECOVERY	- 5,145	
TECHNICALLY AVAILABLE	5,761	
ADJUSTMENT FOR COMPETING USES	0	
ECONOMICALLY AVAILABLE	**5,761**	

Forest Products Manufacturing Residuals

The Taos region is home to a number of small commercial-scale forest products manufacturing operations. Table 14 lists existing forest product enterprises and Figure 7 maps their locations.[26] Many, if not most, sawmills in the area manufacture a variety of wood products, including vigas, latillas, posts, poles and/or firewood. Many of the facilities generate a range of forest products manufacturing residuals including byproducts in the form of sawdust, bark, hog fuel (blend of sawdust and bark), chips and shavings. In the Taos region, these residuals are utilized for value-added end uses such as soil amendment products (compost/mulch), landscape cover, fuel pellets or animal bedding. Interviews with sawmill owners and the New Mexico Forest Industry Association[27] confirmed that these end uses represent well-developed markets. For the purpose of this feedstock availability analysis, TSS found that forest products manufacturing residuals generated within the TSA are already committed to well established markets and are not considered economically available.

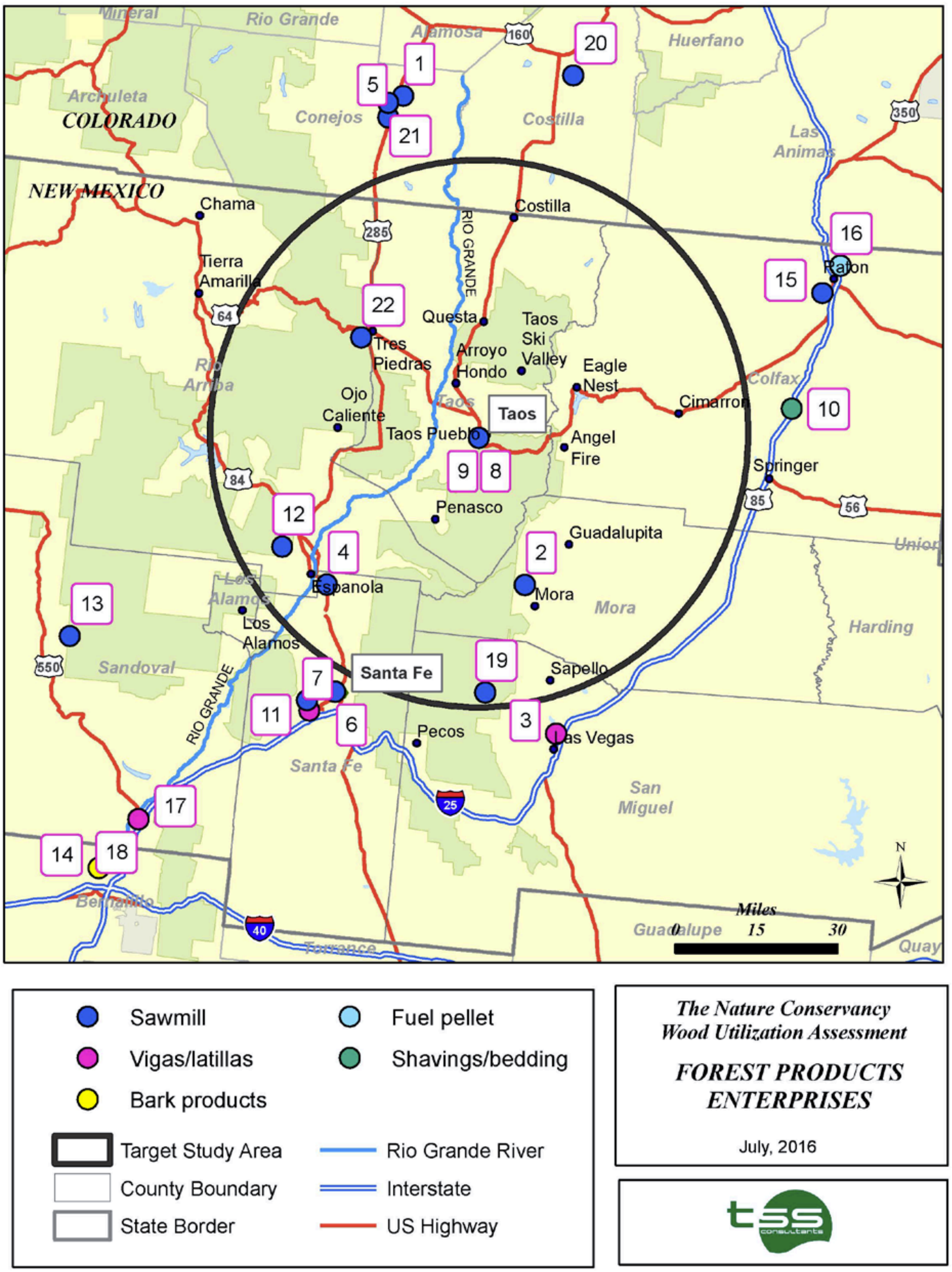
[26] Data supplied by Forest Industry Research Program, Bureau of Business and Economic Research, University of Montana, personal communication, Chelsea McIver, Research Specialist, June 2016, and the New Mexico Forest Industry Association.
[27] Discussions with Jose Valera Lopez, Executive Director, New Mexico Forest Industry Association.

Table 14. Forest Products Enterprises Active in the TSA Region

MAP NO.[28]	FACILITY NAME	FOREST PRODUCT TYPE	COUNTY	TOWN
1	Allpine Lumber	Sawmill and house logs	Conejos	La Jara
2	Aspen Tree Farm and Sawmill	Sawmill	Mora	Mora
3	Barela Timber Mgmt. Co., Inc.	Vigas and latillas	San Miguel	Las Vegas
4	Conley Lumber Mill LLC	Sawmill	Rio Arriba	Espanola
5	Guymon Ltd.	Sawmill	Conejos	La Jara
6	Hansen Lumber Co	Sawmill	Santa Fe	Santa Fe
7	Norton Hill Wood Co	Vigas and latillas	Santa Fe	Santa Fe
8	Olguin's Sawmill and Firewood	Sawmill and firewood	Taos	Taos
9	Olguin's Sawmill and Vigas	Vigas and latillas	Taos	Taos
10	Silver Dollar Racing & Shavings	Shavings/ animal bedding/wattles	Colfax	Maxwell
11	Spotted Owl Timber Inc.	Sawmill	Santa Fe	Santa Fe
12	W. H. Moore Cash Lumber	Sawmill	Rio Arriba	Hernandez
13	Walatowa Timber Industries	Sawmill	Sandoval	Jemez Pueblo
14	Western Organics	Bark products	Bernalillo	Bernalillo
15	Western Wood Products	Sawmill and post/pole	Colfax	Raton
16	Western Wood Products	Fuel pellet	Colfax	Raton
17	Wholesale Timber and Vigas	Sawmill	Sandoval	Bernalillo
18	Wholesale Timber and Vigas	Vigas and latillas	Sandoval	Bernalillo
19	Wolf of the Woods Sawmill	Sawmill	San Miguel	Montezuma
20	Blanca Forestry Products Inc.[29]	Sawmill	Costilla	Fort Garland
21	Quality Timber	Sawmill	Conejos	La Jara
22	Kuykendall	Sawmill and firewood	Rio Arriba	Tres Piedras

[28] Map Numbers refer to business locations shown in Figure 7.
[29] Trinchera Ranch, Blanca Forest Products, is a proposed sawmill currently under development.

Figure 7. Forest Products Enterprises Map for the TSA Region



Electrical Transmission/Distribution System Right of Way

Kit Carson Electric Cooperative is the primary electric service provider within the TSA. An interview with Kit Carson management staff[30] confirmed that the cooperative maintains over 2,500 miles of power lines, employing two line maintenance crews full time. All hazard trees removed are left on site as they are considered property of the landowner. Kit Carson staff could not provide an estimate of logs left on site, but noted that access to many of these down logs is very limited due to existing roads that were not designed to accommodate log or chip trucks. Limbs and debris that are removed are chipped and blown into 10-yard box trucks, with the chips delivered to homeowners for use as soil amendment. There is currently a waiting list for the chips. Due to very limited access to logs and existing markets for wood chips, TSS found that there is no woody biomass material available from electrical transmission/distribution system right of way maintenance operations.

Summary of Forest-Sourced Biomass Availability

Table 15 summarizes forest biomass availability within the TSA.

Table 15. Forest and Pinyon-Juniper Woodland Sourced Biomass Availability

SOURCE	POTENTIALLY AVAILABLE (BDT/YEAR)	TECHNICALLY AVAILABLE (BDT/YEAR)	ECONOMICALLY AVAILABLE (BDT/YEAR)
Timber Harvest Residuals	6,085	3,189	3,189
Forest Restoration and Fuel Treatment Residuals	34,095	17,878	17,878
Pinyon Juniper Treatment Residuals	10,905	5,761	5,761
Forest Products Manufacturing Residuals	0	0	0
Electric Transmission/Distribution System Maintenance	0	0	0
TOTAL	**51,085**	**26,827**	**26,827**

Urban-Sourced Biomass

Construction and Demolition Wood

Residents, businesses, and construction projects within the TSA regularly produce wood waste in the form of construction debris, demolition wood, and industrial byproducts (e.g., wood pallets). Based on TSS' research on urban waste generation in New Mexico, approximately 5.3 pounds per capita of municipal solid waste (MSW) is generated daily in the region that includes Los Alamos, Mora, Rio Arriba, Santa Fe, San Miguel, and Taos counties (Enforcement Area II, NM

[30] Richard Martinez, Chief Operating Officer.

Solid Waste Bureau, 2008 data).[31,32] Population within the TSA was estimated using county and town census data (US Census Bureau). 2013 estimates generated by the US Environmental Protection Agency (EPA) indicate about 6.2% percent of the solid waste stream is made up of wood waste.[33] Urban wood feedstock is assumed to have a 20% moisture content factor.[34] Approximately 1,591 BDT per year of clean construction and demolition wood are potentially available within the TSA. Based on TSS' experience, approximately 65% of this potential volume of construction and demolition wood is recoverable as clean[35] wood waste and is considered technically available at 1,034 BDT per year. Currently, there are no competing uses for clean construction and demolition wood so the technically available volume of 1,034 BDT per year is also the economically available estimate. Table 16 summarizes construction and demolition wood waste availability.

Table 16. Construction and Demolition Wood Waste

SOURCE	2013 POPULATION	WASTE TOTAL VOLUME (LBS/YEAR)	WOOD WASTE VOLUME (LBS/YEAR)	WOOD WASTE FEEDSTOCK (BDT/YEAR)
All or part of Taos, Colfax, Rio Arriba, Santa Fe and Mora Counties	82,421	64,167,951	3,182,730	1,591
POTENTIALLY AVAILABLE				1,591
ADJUSTMENT FOR RECOVERY				-557
TECHNICALLY AVAILABLE				1,034
ADJUSTMENT FOR COMPETING USES				0
ECONOMICALLY AVAILABLE				**1,034**

<u>Residential Tree Trimming Wood Waste</u>

EPA estimates from 2013 indicate that approximately 13.5% of the municipal waste stream is made up of residential tree trimmings suitable for feedstock. However, TSS assumes that only about 80% of this wood waste is recoverable[36] as biomass feedstock. Limbs and other green waste (brush) is typically 50% moisture. Residential woody debris and tree trimming materials in small towns and rural areas in New Mexico are often used for firewood and not hauled to a

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[31] 2009 New Mexico Solid Waste Annual Report, NM Environment Department, Solid Waste Bureau https://www.env.nm.gov/swb/documents/2009FinalAR.pdf

[32] The NM statewide rate is 5.6 lbs. per capita per day; "The State of Garbage in America, 17th Nationwide Survey of MSW Management in the US." Biocycle, October 2010.

[33] US EPA, Advancing Sustainable Materials Management: 2013 Fact Sheet, June 2013: https://www.epa.gov/sites/production/files/2015-09/documents/2013_advncng_smm_fs.pdf

[34] From TSS' experience procuring urban wood waste feedstocks.

[35] Clean wood waste is woody debris that is free of paint, resins, pesticides or chemical treatment.

[36] From TSS' experience procuring urban wood waste feedstocks and discussions with waste managers.

regional transfer station or landfill for disposal. For this analysis, TSS assumes that 60% of the technically available tree trimming material is utilized by homeowners as firewood.
Table 17 summarizes residential tree trimming wood waste availability.

Table 17. Residential Tree Trimming Wood Waste

SOURCE	2013 POPULATION	WASTE TOTAL VOLUME (LBS/YEAR)	WOOD WASTE VOLUME (LBS/YEAR)[37]	WOOD WASTE FEEDSTOCK (BDT/YEAR)
All or part of Taos, Colfax, Rio Arriba, Santa Fe and Mora Counties	82,421	1,324,364	89,395	45
POTENTIALLY AVAILABLE				45
ADJUSTMENT FOR RECOVERY				-9
TECHNICALLY AVAILABLE				36
ADJUSTMENT FOR COMPETING USES				21
ECONOMICALLY AVAILABLE				**14**

<u>Summary of Urban-Sourced Biomass Availability</u>

Table 18 summarizes urban biomass availability within the TSA.

Table 18. Urban-Sourced Biomass Availability

SOURCE	POTENTIALLY AVAILABLE (BDT/YEAR)	TECHNICALLY AVAILABLE (BDT/YEAR)	ECONOMICALLY AVAILABLE (BDT/YEAR)
Construction and Demolition Wood Waste	1,591	1,034	1,034
Residential Tree Trimming	45	36	14
TOTAL	**1,636**	**1,070**	**1,048**

Findings

Summarized in Table 19 is the biomass feedstock supply availability by source.

[37] Dry weight.

Table 19. Summary of Biomass Feedstock Supply Availability

SOURCE	POTENTIALLY AVAILABLE (BDT/YEAR)	TECHNICALLY AVAILABLE (BDT/YEAR)	ECONOMICALLY AVAILABLE (BDT/YEAR)
Timber Harvest Residuals	6,085	3,189	3,189
Forest Restoration and Fuel Treatment Residuals	34,095	17,878	17,878
Pinyon Juniper Treatment Residuals	10,905	5,761	5,761
Forest Products Manufacturing Residuals	0	0	0
Electric Transmission/Distribution	0	0	0
Construction and Demolition Wood Waste	1,591	1,034	1,034
Residential Tree Trimming	45	36	14
TOTAL	**52,721**	**27,897**	**27,876**

BIOMASS FEEDSTOCK COMPETITION ANALYSIS

In order to forecast the economic availability of biomass feedstock, it is critical to understand both current market demand and potential market demand. If there are established, well-developed markets within the TSA, these need to be considered when calculating feedstock availability. In addition, potential and emerging markets should be noted, as these markets may impact future availability.

Current Competition

At this time there are no established, consistent markets for woody biomass material generated within the TSA. The community of Angel Fire is utilizing some processed forest biomass as landscape cover and soil amendment, which is made available at no cost to local residents. Santa Fe Community College has installed a district heating system that is fired on woody biomass material. Discussions with a biomass fuel supplier[38] that has delivered to the college, confirmed that the college operates the facility intermittently.

Potential Competition

There are a number of value-added utilization technologies that show promise, and these are discussed in the Value-Added Opportunity Analysis section of this report. One of the more promising, homegrown technologies is a plastic/wood fiber composite that is being marketed by Altree.[39] Based in Albuquerque, this firm holds several patents for the production of composite panels that can be used as an alternative to material such as aluminum. Altree's principal[40] expressed a strong interest in locating a commercial-scale facility in northern New Mexico.

[38] Terry Conley, TC Company, Espanola, New Mexico.
[39] http://www.altree.com/
[40] Tony Burger, CEO, Altree.

REGIONAL BIOMASS FEEDSTOCK UTILIZATION INITIATIVES

In recent years, there have been a number of initiatives seeking out alternative uses for excess woody biomass material generated as a byproduct of restoration/fuels treatment activities that is currently left on site, piled and burned, loped and scattered, or chipped and scattered. Coordinating with these initiatives to compare notes on utilization alternatives and potential synergies could well facilitate a regional approach that optimizes outcomes and strategies focused on the shared objectives of watershed restoration and fire resilient landscapes. Table 20 summarizes initiatives underway located tributary to the TSA.

Table 20. Biomass Utilization Initiatives Adjacent to the TSA

INITIATIVE SPONSOR	VALUE-ADDED PROCESS TARGETED	CONTACT INFORMATON	NOTES
Altree	Plastic/wood fiber composite.	http://www.altree.com/	Targeting Northern NM for a commercial-scale facility.
Blanca Forestry Products Inc.	Sawmill with dry kiln and planer.	Vincent Corrao, CEO, Northwest Management, Inc. (208) 883-1098	Located at Fort Garland, CO. Commercial-scale sawmill that should commence operation Q4 2016.
Chama Peak Land Alliance	Biomass power and/or advanced biofuels.	http://chamapeak.org/	Have conducted feedstock availability assessment and wood utilization study.
Renewable Forest Energy, LLC	Sawmill and biomass power generation facility.	James R. Ford, CEO	Plan to locate sawmill and small-scale biomass power generation facility near Pagosa Springs, CO. Currently implementing a stewardship contract on the San Juan NF.
Rio Grande Water Fund	No specific technology or process selected.	http://www.nature.org/ riogrande	Large partnership with the shared goal to restore 30,000 acres of forest per year in four focal areas that include much of the study area.
Rio Grande Watershed Emergency Action Coordination Team	Now conducting analysis.	http://www.rweact.org/	Focused on Hinsdale, Mineral and Rio Grande counties. Targeting the upper Rio Grande watershed in the San Luis Valley.
Walatowa Timber Industries	Sawmill and residential fuel pellet facility.	http://www.walatowatimber.com/	Located on the Jemez Pueblo. Recently secured a 10-year stewardship contract with the Santa Fe NF.

COSTS TO COLLECT, PROCESS AND TRANSPORT BIOMASS FEEDSTOCK

There are few commercial-scale contractors equipped to collect, process, and transport forest and pinyon-juniper biomass material operating within the TSA. Round wood is typically removed for sawlogs, firewood, vigas or latillas. Limbs, tops and small stems are typically piled and burned, lopped and scattered, chipped and scattered or occasionally left on site.

Delivered Cost Forecast

TSS relied on discussions with forest biomass contractors operating in the region, in addition to TSS's past experience, to analyze these costs. Table 21 provides results of the cost review.

Table 21. Biomass Feedstock Collection, Processing, and Transportation Costs

SOURCE	LOW RANGE ($/BDT)	HIGH RANGE ($/BDT)	AVERAGE DELIVERED COST ($/BDT)
Timber Harvest Residuals	$56.25	$61.25	$58.75
Forest Restoration and Fuel Treatment Residuals	$46.25	$50.00	$48.13
Pinyon Juniper Treatment Residuals	$47.50	$51.25	$49.38
Urban Wood Waste	$36.25	$41.25	$38.75

Assumptions used to calculate range of costs summarized in Table 21:

- One-way transport averages 30 miles for biomass material;
- Timber harvest residuals are collected and processed into truck (at the roadside landing) for $30 to $35 per BDT;
- Forest restoration and fuels treatment residuals are harvested, collected, and processed into truck (at the roadside landing) for $40 to $47.50 per BDT;
- Pinyon juniper treatment residuals are collected (including hand piles) and processed into truck (at the roadside landing) for $42.50 to $50 per BDT;
- Service fees or cost share are available from public agencies (e.g., USFS, BLM, NRCS, Soil and Water Conservation Districts, NM State Forestry) to offset one-half of the cost of collection, processing, of forest restoration, fuels treatment and pinyon-juniper treatment residuals;
- Tip fees collected at the landfill or transfer station offset the cost of urban wood waste sorting and collection;
- Urban wood waste processing costs range from $10 to $15 per BDT;
- Haul costs are $105 per hour for walking floor chip truck trailer; and
- Forest and pinyon-juniper biomass chip removals average 14 BDT per truckload.

VALUE-ADDED OPPORTUNITIES ANALYSIS

Using findings from the biomass feedstock supply availability analysis, field visits in the Taos area, interviews with existing wood products and waste facilities, and potential new wood products developers, TSS conducted a value-added opportunity review to assess the range of commercial utilization options available. The emphasis of this analysis is focused on utilization of feedstocks deemed available over and above feedstock types and volumes used by existing commercial enterprises sourcing feedstocks from within the TSA. Thus, the biomass feedstock to be principally considered in the value-added opportunities analysis is that biomass waste material that would be derived from forest hazardous fuels reduction, timber harvest operations, forest restoration and landfill wood waste recovery activities.

In addition, there also exists the potential for increased fuels reduction and forest restoration activities in the Taos TSA. Table 22 provides estimates of the incremental amount of annual acreage needed, based on total biomass feedstock utilized, by vegetation cover type.

Table 22. Average Acres of Forest Restoration/Fuels Reduction Activities

VEGETATION COVER TYPE AND ACTIVITY	AVERAGE BDT PER ACRE	ACRES/YEAR OF RESTORATION/REDUCTION NEEDED PER VOLUME OF WOODY BIOMASS IN BDT				
		2,500 BDT	5,000 BDT	15,000 BDT	30,000 BDT	120,000 BDT
Pinyon-Juniper Fuels Reduction	5 to 7 average of 6	417 acres	834 acres	2,500 acres	5,000 acres	20,000 acres
Mixed Conifer and Ponderosa Pine Restoration and Fuels Reduction	7 to 10 average of 8.5	294 acres	588 acres	1,765 acres	3,529 acres	14,117 acres

Value-Added Opportunities Matrix

Based on TSS experience with value-added utilization of woody biomass, and in consultation with TNC, five categories of value-added products were selected for analysis for potential utilization within the Taos region. These are:

- Biomass Power and Thermal Energy
- Densified Fuelwoods
- Co-location with Existing Sawmill Facility
- Agriculture, Landscaping and Furniture
- Advanced Wood-based Materials and Biofuels

Within each of these value-added product categories, specific processes and products are identified in Table 23. Along with the listing of the specific value-added processes and products TSS has indicated, various parameters by which to present each value-added product, such as feedstock specifications, type of equipment needed, general market potential, and specific and general comments about the specific process and products are presented.

Table 23 has estimates of the amount of woody biomass material required annually to support the respective utilization activity at an economic scale. Table 23 also focuses on utilization of feedstocks deemed available over and above feedstock types and volumes used by existing commercial enterprises sourcing feedstocks from within the TSA.

Table 23. Value-Added Biomass Utilization Opportunities for Northern New Mexico

Biomass Power and Thermal Energy

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	FEEDSTOCK UTILIZATION SCALE (BDT IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
Small to Commercial Scale Biomass Combined Heat and Power (Solid Fuel Steam Cycle)	Woody biomass chipped to 3"minus, 50% mc, 3% ash. Drier feedstock preferred.	Feedstock handling, boiler, steam cycle turbine-generator, emissions control, water-cooling and recovery.	Technology is evolving quickly and slowly becoming more cost effective.	More appropriate where electrical and thermal energy wholesale rates are high. Typically found in states with attractive Renewable Portfolio Standards or renewable energy incentives.				X	X
Biomass Heating for Buildings	Woody biomass chipped to 3"minus, 50% mc, 3% ash.	Boiler system and hot water or steam delivery system.	Especially cost effective if replacing existing heating oil or propane heat. Can use for cooling also (using absorption chillers).	Feedstock sizing has been an issue with recently installed thermal energy facilities. Typical installations include schools,	X	X			

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	FEEDSTOCK UTILIZATION SCALE (BDT IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
				hospitals, and community buildings.					
Gasification Combined Heat and Power	Woody biomass chipped to 3"minus, 30% mc, 3% ash. Feedstock needs to be around 20% or lower moisture content.	Gasifier, gas cleanup, IC engine or turbine-generator.	Technology is evolving quickly and slowly becoming more cost effective.	More appropriate where electrical and thermal energy wholesale rates are high or in remote installations where power is not currently available.			X	X	
Pyrolysis/ Torrefaction (Charcoal & Biochar)	Wood pieces (flexible spec).	Charcoal kiln or Pyrolysis Reaction Unity.	Charcoal: for cooking, artist's charcoal. Biochar for soil amendment, water/waste water filtration, other emerging uses. Energy product: Co-firing in coal power	Charcoal is from slow pyrolysis. Energy product from mild pyrolysis (torrefaction) is torrefied feedstock and can be highly marketable due to BTU/pound and impervious to water. Coal is a key solid			X	X	

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	FEEDSTOCK UTILIZATION SCALE (BDT IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
			plants (no modifications required to coal handling systems) or as feedstock supplement for biomass power plants	fuel in the marketplace and tends to set the price point.					

Densified Fuelwoods

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (BDT IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
Fire Logs (Manu-factured)	Clean, dry (<10% mc) chip, needs to be <1% ash.	Log machine, dryer, cooler, hammermill, and packaging.	Substitute for firewood is the primary market.	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.		X	X	X	
Wood Fuel Pellets	Clean, dry (<10% mc) chip, needs to be <1% ash.	Pellet mill, dryer, cooler, hammermill, and packaging.	Domestic users now, but potential for biomass boilers. At the industrial scale	Use of either roundwood or biomass from forest possible (e.g., small logs or chips			X	X	X

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (BDT IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
			can be co-fired with coal. Could also be marketed to international markets.	low in bark). Key issue and expense is drying system. Larger scale facility may face challenges in gaining market share for domestic stoves. Large-scale export facility may have feedstock sourcing challenges and exposure to currency exchange rate risk.					
Fuel Bricks	Chip, dry (<15% mc), needles, bark okay.	Brick machine, possible dryer, cooler, hammermill, and packaging.	Substitute for firewood is the primary market. Domestic use or camping, lighter and more portable.	May use needles, bark and paper. Potential to use field-dried material as feedstock. Bricking machine can be small and portable.	X	X	X		

Co-location with Existing Sawmill Facility

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
Post and Pole Agriculture	Straight, low taper softwood (lodgepole, ponderosa) is preferred.	Rosser head peeler and/or doweller. Sorting line. Bucking saw.	Market for fencing, landscaping, outdoor latillas, vineyard trellising.	Typically sold without stripping bark or treating the wood. Small 2-5 inch diameter can be utilized.	X	X	X	X	
Post and Pole Architecture	Straight, low taper softwood (lodgepole, ponderosa) is preferred.	Rosser head peeler and/or doweller. Sorting line. Bucking saw.	Sold to treating facilities or direct to clients. Market for vigas and latillas. Market for outdoor uses for treated wood in patios or landscaping.	Higher quality preferred. Dried (air or kiln dried) and sometimes treated. Small 1-5" diameter for latillas, larger 6-20" diameter for vigas and home building.	X	X	X	X	
Lumber Kiln	Lumber products or firewood.	Kiln (steam or dehumidifier).	Kiln dried lumber has added value in the market place. Transport of dried lumber products is	Could also dry firewood or heat treat lumber and packaging to meet ISPM15 (treatment standard for		X	X	X	

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
			more cost effective (due to lower weight).	wood shipped internationally). Could use waste wood as a feedstock source for the heating.					

Agriculture, Landscaping, and Furniture/Outdoor Recreation

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
Decorative Bark	Small roundwood that is easily de-barked. Raw bark from sawmills is common source.	Debarker (flail, ring or rosser head), screen (trommel or flat).	Higher value in urban communities.	As sawmill residuals become scarce, value of bark for landscape cover increases. Alternative use is hog fuel.	X	X	X	X	
Decorative Chip	Bark free and sized (no fines) wood chip.	Debarker (flail, ring or rosser head), screen (trommel or flat).	Colorized landscape cover sold in bulk and/or bagged.	Colored landscape cover requires additional equipment (colorizer). Note that bark free chip has alternative markets such	X	X	X	X	

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
				as pulp/paper or furnished for composite products (particleboard/ hardboard/ decking).					
Compost	Tree trimmings and grass clippings (greenwaste).	Grinder, screen and windrow turner.	Soil amendment market is seasonal. Typically sold in bulk or bagged.	A compost operation near an existing landfill diverts greenwaste from landfills. Compost and mulch operations work best on same site.	X	X	X	X	
Animal Bedding (Shavings)	Small roundwood (ponderosa pine preferred).	Shaver, screens, drying, packaging.	Can be sold in bulk and/or bagged.	Shavings are produced from roundwood, including small diameter material. Chipped biomass or mill sawdust can also be used for animal bedding, (but are not	X	X	X	X	

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
				considered shavings). Local existing sawmills could add animal bedding systems to their operations.					
Greenhouse and Nursery	For heating: woody biomass chipped to 3"minus, 50% mc, 3% ash.	For chipping: debarking equipment (e.g., chain flail) chipper and screen. For heating: biomass boiler and hot water or steam delivery system.	A greenhouse facility integrates the use of several types of chipped biomass into one business enterprise.	Greenhouses utilize several wood waste streams. Chips could be used on pathways or under benches and as a mulch or soil additive. Thermal energy system could utilize woody biomass for heating and cooling.	X	X	X	X	
Furniture/Out-door Recreation Sets	Small to medium roundwood.	Debarker, head rig, resaw, edger. Woodworking and cabinetry	Sold to individual furniture craftsmen, or built and sold	Wood needs to be dried. Potential for a commercial outlet or	X	X	X		

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
		equipment.	on-site at a sawmill.	gallery in urban communities.					

Advanced Wood-based Materials and Biofuels

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
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.	Landscape (bender board), decking, fencing, park furniture (picnic tables and seats), outdoor signage. Composite wood furniture market is growing due to interest in sustainability. Increasingly used in building, 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. Altree is a wood plastic material that can include pinyon-juniper and other		X	X	X	X

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
				softwoods. Blending (compounding) of wood and plastic may be two processes or single process depending upon equipment. Commercial molding processes typically continuous extrusion or batch injection molding.					
Compound Pellets for WPC Production	Clean, dry (2-8% mc) wood flour. Wood is ~55% of feedstock along with plastic and additives. Recycled wood use common.	Compounder extruder.	Existing WPC mills.	Cheaper way to get into WPC market place than making finished products.			X	X	X
Chip for Pulp/Paper or Composite Panel Furnish	Woody biomass chipped to 3"minus, 50% mc, bark free with few fines.	Debarking equipment (e.g., chain flail) chipper and screen.	No virgin pulp/paper operations in the region.	No virgin paper mills in NM, some secondary mills utilizing			X	X	X

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
				manufactured paper or recycled paper.					
Veneer	Straight logs with limited taper. 8"+ diameter.	Steaming vats, veneer lathes, trimming, rolling stock.	Plywood and LVL mills are in Oregon, peeler cores (2"-4") sold into post and pole market.	Typically a large commercial-scale facility (process 420 blocks per hour).			X	X	X
Air Filtration Media	Virgin material that will grind to large consistently sized particles.	Grinder and screen.	Also called bio-filtration. Wastewater treatment facilities, manufacturing with air filtration needs.	Need a second market for grinder material that does not meet specifications for filtration media; e.g., hog fuel or landscaping.		X	X	X	
Biofuels	Wood waste, forest harvest and thinning residues.	Grinder or chipper and screens.	Use as alternative transportation fuels (renewable diesel, jet fuel).	Due to economies of scale, commercial facilities will need to be large with considerable feedstock needs.					X

PROCESS OR PRODUCT	FEEDSTOCK SPECIFICATIONS	MAIN EQUIPMENT	MARKET POTENTIAL	COMMENTS	PROJECT VIABILITY LEVEL BY BDT (IN THOUSANDS PER ANNUM)				
					≤2.5	5	15	30	120
Essential Oils	Pinyon pine and Juniper. Chipped or shredded.	'Extractives' distillation done in a still with boiling water. Can use biomass heat source.	Aromatherapy and additive to lotions or soaps.	Marketing for retail or internet sales and distribution.	X	X	X		

Critical Attributes for Value-Added Utilization

To assist in determining which value-added opportunities identified for the Taos TSA might be the most appropriate path forward, each of the value-added utilization categories is presented below in Table 24 with a discussion of how each of the critical attribute is key to the successful deployment of the value-added utilization technology. The critical attributes identified in the project scope of work are:

- Minimum economic scale
- Types of feedstock utilized
- Existing and potential markets
- Transportation to markets
- Synergies for co-location in existing sawmill or product yard
- Ease of facility siting
- Workforce requirements
- Environmental permitting and compliance
- Potential project partners

Table 24. Critical Attributes for Value-Added Utilization by Categories

BIOMASS POWER AND THERMAL ENERGY	
Minimum economic scale	Dependent on local and regional energy prices (for power), and type of fossil fuel offset (fuel oil, propane or natural gas). For power, systems under 3 MW (approximately 24,000 BDT annual feedstock requirement) without a significant use of waste heat as an additional source of revenue is difficult. The relatively low costs of electricity in New Mexico adversely affect the economics of biomass power. Retail residential electricity prices average 11.37 cents/kWh, with the average commercial and industrial retail electricity costs at 9.32 cents/kWh and 5.83 cents/kWh respectively.[41] Thermal only biomass utilization is dependent on thermal demand and existing fuel offset (fuel oil, propane or natural gas). Thermal uses (primarily space and water heating in the northern New Mexico) will likely use much smaller amounts of biomass feedstock than electric power generation. Pyrolysis of woody biomass and the production of biochar can be

[41] New Mexico Electricity Rates and Consumption, http://www.electricitylocal.com/states/new-mexico/

	accomplished as a stand-alone process and at relatively small scale if there are adequate local and regional markets.
Types of feedstock utilized	Woody biomass. Leaves, needles, very fine biomass (< 1/8") such as sander dust not usable as a direct feedstock.
Existing and potential markets	Local and regional electric transmission grid exists; however, retail electricity prices in northern New Mexico are very low. Thermal loads exist at schools, hospitals/clinics, government offices, and possible larger businesses and commercial facilities. Although there is not an existing market for biochar in New Mexico, there are evolving and potential uses such as soil amendments (combining with compost in particular) and perhaps mining reclamation.
Transportation to markets	Electricity via power transmission grid. Thermal use is site/facility specific. Biochar would require transportation to non-local markets until such are developed locally and regionally.
Synergies for co-location in existing sawmill or product yard	Biomass power plant or pyrolysis facilities can supply waste heat to a wood products yard for various purposes such as lumber/firewood drying. A stand-alone pyrolysis unit could supply syngas as a substitute for natural gas or propane at co-located facilities. A gasification to electricity plant can also produce biochar as a byproduct (and also generate waste process heat).
Ease of facility siting	Power plant facility should be near economic interconnect with electricity grid (distribution system). Biomass thermal requires a host for the heat, such as a building or group of buildings (i.e., school, government building campus, hospital campus, etc.). Stand-alone pyrolysis and the production of biochar can be sited in various places, as long as land use entitlements allow such processing operations.
Workforce requirements	Very dependent on use option. A large biomass fired power plant (20 MW+) can employ many employees, both at the facility and in field collecting, processing, and transport, in the order of approximately five employees per megawatt installed.[42] The standard metric for amount of woody biomass required to sustain a power plant annually is approximately 8,000 BDT per megawatt of capacity. Of the five employees, four would be those that collect, process, and transport the waste biomass to the power plant facility. For a stand-alone pyrolysis facility, the power plant metric could likely be similar, with the annual use of 8,000 to 24,000 BDT requiring similar manpower, both at the facility and in the field. In contrast, biomass thermal use, particularly in more rural environments, uses much less biomass and is usually decentralized,

42 The Value of the Benefits of U.S. Biomass Power, National Renewable Energy Lab, November 1999.

	i.e., biomass-heating units are installed for individual buildings or facilities. For example, a school with several classrooms and other buildings and rooms to heat might only use 800 BDT per year. And generally, personnel who operate the existing heating systems can operate a biomass heating system.
Environmental permitting and compliance	Depending on the size and type of biomass power plant or stand-alone pyrolysis facility proposed, permitting can be relatively straight forward, or in the case of a large direct combustion facility more complex. In New Mexico, a community-scale biomass power plant (< 5 MW), particularly if gasification to internal combustion engine electricity generator set is used, has relatively low air pollutant emissions, making air quality permitting relatively simple and may require only a minor construction permit from the New Mexico Air Quality Bureau. A direct fired biomass plant, particularly those exceeding 8 MW, can have more complex air quality permitting and may require a Title V air permit from the New Mexico Air Quality Bureau, not to mention the need for wastewater discharge handling that may require evaporation ponds and corresponding permitting, which like air quality, will require project operations monitoring. Biomass thermal heating systems are generally a small emitter of air pollutants and may be able to qualify for No Permit Required status from the New Mexico Air Quality Bureau. Larger systems may have to apply for a minor construction permit. Biomass power plants producing electricity for commercial sale are also subject to land use entitlement requirements of local county, city (or town), or pueblo land use regulations, and will generally require special or conditional use permits issued by local planning departments and planning commissions. Thermal heating systems using biomass basically substitute for existing heating systems and do not usually require any modifications to land use entitlements.
Potential project partners	Bioenergy power plant developers, local utilities or electric cooperatives, energy service companies (ESCO), local or tribal government, building or facility owners, and ski resorts.
DENSIFIED FUELWOOD	
Minimum economic scale	Relatively low capital costs for waste wood processing equipment for fuel brick, fire logs, or pellet mill (the latter depending on feedstock throughput). Fuel brick/log/pellet enterprises can start with a low level of material and ramp up if successful.
Types of feedstock utilized	Roundwood hardwood (aspen/oak) not suitable for lumber is available for firewood. Pinyon and Juniper from restoration projects could be abundant. Softwoods such as ponderosa pine are more readily available than hardwood. Fuel bricks may be able to take advantage of multiple feedstock sources.

Existing and potential markets	There are well-developed local and regional firewood markets that a commercial-scale firewood processing facility could serve. There may be an opportunity to sell packaged pellets and firewood into regional and external markets. Most of the local markets are well served by existing firewood enterprises. Fuel bricks reportedly can readily use the needles and sawdust from waste woody biomass sources, which makes that process very appealing when using waste woody biomass from hazardous fuels reduction projects in the region.
Transportation to markets	Firewood as a low-cost heating source is well established in local markets within the Northern New Mexico region. Santa Fe and Albuquerque markets are within economic transport distance of Taos. Densified fuels such as bricks and pellets have potential depending on costs of processing (densify) the woody biomass.
Synergies for co-location in existing sawmill or product yard	Co-location and collaboration with a sawmill is desirable. May need a dry kiln or related equipment, which could be shared with co-located businesses. For example, a dry kiln could dry both lumber and firewood. Rolling stock (loaders, fork lifts) and on site personnel could be shared.
Ease of facility siting	These types of facilities would likely be best suited for siting at existing wood products manufacturing facilities or solid waste transfer/processing facilities and landfills.
Workforce requirements	Nearly all workers can receive on-the-job training. Larger facilities (e.g., pellet processing) would require some specialized expertise (such as boiler operator and machinist). Depending on feedstock throughput, the wood fuel pellet scenario could employ up to 60+ personnel. The fuel brick scenario could be sized at smaller amount, but there could be several facilities, some mobile, that could have 2 to 6 personnel each.
Environmental permitting and compliance	Permitting would be limited primarily to air quality and land use entitlement. The various production methods may have mechanical drying of the woody biomass, which would emit volatile organic compounds and may require an air quality permit. A large-scale firebrick, fire log or pellet plant may also have boiler system for drying and manufacturing those products that would require an air quality permit. Any stationary manufacturing facility development would likely require a special use permit or conditional use permit. A mobile facility, such as fuel brick processor, would likely not.
Potential project partners	The densified fuel industrial sector is relatively small. Smaller startups, and the ability of such manufacturing to be somewhat modular, will likely be the norm. However, they will need to have the necessary marketing partners, particularly in the retail sector, to sell densified fuel wood products. Partners would be those retail outlets that traditionally sell such products.
CO-LOCATED WITH EXISTING SAWMILL FACILITY	

Minimum economic scale	Co-locating can allow for small-scale startup ventures, particularly if the new value-added utilization manufacturing process is owned (or partly owned) by the existing sawmill owner/operator. Co-location with sawmill facilities could allow for infrastructure, equipment, labor, product marketing efforts, and capital expenses to be shared between existing and new wood products. It is critical that the new value-added utilization at the minimum economic scale generate enough revenue to address capital expense, labor, and operations/maintenance expenses to generate acceptable profit for the products produced.
Types of feedstock utilized	Post and poles need straight low tapering softwood (ponderosa pine preferred) that could be sorted from incoming log deliveries. Kilns could dry dimension lumber and/or firewood, using sawmill or forest residuals as fuel. Much of the forest restoration and fuel treatment residuals, and the pinyon juniper treatment residuals, will be on the smaller diameter material not currently used for vigas and latillas.
Existing and potential markets	There is an existing market for roundwood use in northern New Mexico as vigas, latillas, coyote fencing, and posts/poles. Post and pole markets in the region have reportedly been challenging. Kiln dry lumber could be utilized in the regional market. Kiln dry firewood could also be used in the robust regional firewood market but would compete with lower cost non-dried firewood.
Transportation to markets	Transportation to the Santa Fe and Albuquerque markets has potential depending on costs of producing posts and poles from forest residuals. Although the cost of drying lumber or firewood may add to initial cost, its lower weight (per wood volume) will recoup some of that cost.
Synergies for co-location in existing sawmill or product yard	Synergies would be relatively high for post and pole and drying kiln operations at existing sawmill facilities. These added products could fit into the suite of activities that can occur at a sawmill facility while diversifying revenue streams.
Ease of facility siting	There are several, relatively small, sawmills in the Taos TSA, where post and pole operations, dry kilns or densified fuel wood processing could be added.
Workforce requirements	Co-locating will take advantage of existing sawmill facility rolling stock and employees, but if operations ramp up sufficiently, additional employees can be added. In addition, new businesses at an existing facility may aid in workforce retention.
Environmental permitting and compliance	The addition of post and pole production to an existing sawmill facility should not require any new environmental permitting. Dry kilns for lumber or firewood, if small could apply for No Permit status or if larger, a Minor Construction permit from the New Mexico Air Quality Bureau. Densified fuel wood processing should not require any new environmental permitting.
Potential project partners	The sawmill operators are the likely project partners for co-located facilities.

AGRICULTURE, LANDSCAPING, AND FURNITURE/OUTDOOR RECREATION	
Minimum economic scale	The products using waste woody biomass under this category can economically process lower amounts of available woody waste biomass due to relatively low capital expense required. This would be particularly true if such products as decorative bark/chips, animal bedding, and furniture/outdoor recreation sets could be co-located with sawmill facilities or multiple output/product yards where infrastructure, equipment, and labor could be shared. It is necessary at the minimum economic scale that the utilization products generate enough revenue to address capital expense, labor, and operations/maintenance expenses, and generate acceptable profit for the products produced.
Types of feedstock utilized	Feedstock can range from varying sizes of roundwood through forest treatment and restoration residuals, along with urban green waste.
Existing and potential markets	Decorative bark and chips generally have a higher utilization in urban markets, so Santa Fe and Albuquerque are likely better target markets.
Transportation to markets	Although there is a relatively small market for these products in the Taos TSA, it is likely that at commercial-scale, these products would need to be transported to the Santa Fe and Albuquerque markets.
Synergies for co-location in existing sawmill or product yard	Synergies could be very good for decorative bark and chips, animal bedding, and furniture/outdoor recreation sets for co-location, particularly with sawmill facilities. Composting, nurseries, and greenhouses also demonstrate good synergies when co-located, as both nurseries and greenhouses could utilize composted materials as soil amendments.
Ease of facility siting	Most of these uses could be co-located at existing sawmill facilities, solid waste transfer/processing yards and landfills, or nurseries. Facilities could be stand-alone, particularly in the case of greenhouses, with ease of siting dependent on size of facility, and potential expansion.
Workforce requirements	Variable per type of use, size of operations and facilities, and location. If co-located with sawmill or solid waste transfer/processing yards and landfills, workforce could have some sharing arrangements with less new jobs created. Greenhouses, using waste woody biomass for heating, can be constructed and operated in phases, thus creating additional new employment as facility ramps up in size.
Environmental permitting and compliance	Co-locating bark, chip, and animal bedding production at existing facilities would not require much, if any, new environmental permitting. Composting would require permitting by the New Mexico Environment Department, specifically a Ground Water Quality Bureau Notice of Intent and Composting Facility Registration whether or not it is co-located with a solid waste facility. Also, land use entitlement permitting may be necessary, particularly

	for a stand-alone composting facility. If any facility and use under this category uses waste woody biomass for heating (or cooling), depending on size would need to apply for No Permit status or if over 10 tons per year of any criteria pollutant is emitted, a Minor Construction Permit.
Potential project partners	Composting and soil amendment companies, nurseries, retail outlets, and wholesalers that sell decorative bark and chips, furniture/outdoor recreation sets, and animal bedding. For greenhouse, nurseries and food producers (such as fruit and vegetable) retailers and wholesalers, and local and regional food banks.
ADVANCED WOOD-BASED MATERIALS AND BIOFUELS	
Minimum economic scale	Advanced wood-based materials (plastic/wood composites) uses can run the full spectrum of available (or project) waste woody biomass in the Taos TSA. Discussion with composites manufacturer indicates that such operations can begin near the minimum economic scale. Advanced biofuels, on the other hand, are currently dependent on larger scale production facilities. Economies of scale are important to biofuels production due to the specialized equipment and conversion technologies required. However, there are ongoing R&D activities at the national labs, such as Sandia National Lab in Albuquerque, to increase the conversion efficiency of woody biomass to biofuels, which should ultimately allow smaller scale facilities to be economically viable. Plastic/Wood fiber composites are able to take advantage of modular production design. Thus, a Phase I installation of a composite facility can start off at the lower end of the biomass supply availability spectrum and ramp up over time as markets and the feedstock supply chain become more developed. Some plastic/wood fiber composites can fully utilize forest fuels reduction residuals as a primary feedstock, which would be economically advantageous over other uses in this category. Composite pellets (wood and plastic combined), or chips for paper/pulp/furnish, require higher volumes of available biomass due primarily to higher capital costs of facility installation and operation, and have relatively tight feedstock specifications, such as wood chips free of bark and fines. Air filtration media would be similar to the larger virgin wood chips needed for paper/pulp/furnish. Essential oils production is a budding utilization process focused on juniper berries and needles. As a specialty product, it can likely operate economically viable at a smaller scale. As more juniper reduction activities occur, the berries and needles can be harvested

	from the woody biomass residuals.
Types of feedstock utilized	Feedstock in this category runs from forest slash (including bark, needles, and fines) through small to large diameter roundwood. Pinyon-juniper, and possibly urban wood, can also be a feedstock.
Existing and potential markets	Markets for biofuels should continue to grow in the future but are slowed a bit by the current, relatively lower cost of petroleum-based transportation fuels. Other western states, such as California and Oregon, have monetary incentive programs (low carbon transportation fuel standards), which help level the playing fields for biofuels with petroleum-based fuels. Additionally, the federal Renewable Fuels Standard provides monetary incentives, but forest biomass used as feedstock cannot be accessed from federal forests. Potential markets for the plastic/wood fiber composites are reported to be robust in the region and elsewhere. If the plastic/wood fiber composite production facilities were to occur outside of the Taos TSA, the plastic/wood fiber composite pellet production option could be a market opportunity. Utilization processes involving chips for paper/pulp and veneer logs do not currently exist in the northern New Mexico region. And, as previously mentioned, these uses require higher quality chips and roundwood. Air filtration media also requires higher quality chips. The juniper-based essential oils market is not likely to be a large market for regional sourced juniper berries and needles, as it is a cosmetic and health-oriented product, mostly of small batch proportions.
Transportation to markets	Nearly all of these utilization processes and products will need to be transported to markets outside the region. Use of rail infrastructure could be advantageous, especially for larger scale operations.
Synergies for co-location in existing sawmill or product yard	There is some synergy for plastic/wood fiber composites and pelletizing to be co-located with existing sawmills, as such sites have potential space and access to additional wood processing equipment (and storage). Co-location at landfills or transfer stations is also an option (as wood waste and plastic are generated on a consistent basis at these facilities).
Ease of facility siting	Ease of siting is very dependent on utilization process. It may be possible to co-locate the plastic/wood fiber composites with sawmill sites or at solid waste transfer/processing and landfill sites where waste wood and residuals are readily available. Large chip facilities would require considerable siting activities. Generally these larger facilities would require local rail access to move product to outside markets. This would be the same also for a biofuels plant, which must move product to distant markets.

	Essential oils production, being a smaller production line, would have relatively small facilities, which would be easier to site.
Workforce requirements	Larger facilities, such biofuels production and plastic/wood fiber composite production, could have significant employment potential, both on site and in the field collecting, processing, and transporting woody biomass material. As the plastic/wood fiber utilization option could be a modular development, workforce requirements could ramp up as such facilities expand due to market response.
Environmental permitting and compliance	The environmental permitting needs for this category are dependent on the various emissions producing processes within the facility and the size of the facility. Facilities such as large biofuels production operations have numerous potential air pollutant emissions sources, which could significantly increase the permitting needs for the facility. Any facility emitting more than 100 tons of any one criteria air pollutant would require a Title V air quality permit. These are permits with significant compliance requirements. The plastic/wood fiber composites and pellet production facilities air quality permitting would be principally for any heating system used to dry the waste wood to the low moisture content feedstock requirements. The Title V, 100 ton per year threshold could be met if such facilities were very large, but a mid-range size facility may only need a Minor Construction permit from the New Mexico Air Quality Bureau. Essential oils facilities would probably need nothing more than a Minor Construction permit, and likely only the No Permit needed designation.
Potential project partners	Partners could include biofuels production companies, paper/pulp companies, lumber manufacturers, and biofilter companies. Plastic/wood fiber composite companies also are included, but are currently more of start-up company status. Essential oil companies are probably more of a local start-up status as well.

Value-Added Utilization Categories and Potential Projects Identified

A focal point of the work being conducted for the value-added analysis is to identify potential projects that could be established in the Taos region using biomass waste material that would be derived from forest hazardous fuels reduction, timber harvest operations, forest restoration and landfill wood waste recovery activities. Primary consideration is given to opportunities that do not compete with existing wood products businesses and can rely solely on waste biomass material as a primary feedstock. Ultimately, the top two potential value-added projects are to be selected, in coordination with TNC, for detailed analysis and assessment for potential Phase II consideration.

Using Tables 23 and 24, along with site visits to the Taos region, interviews with wood products related facility operators in the region, discussions with various woody biomass users and potential users, and taking into account potential projects that could be deployed in the short to medium term horizon, TSS identified the following projects, or project types, for the Taos region.

- Wood-plastic composites
- Biomass heating systems
- Mine reclamation
- Pyrolysis production of biochar
- Fuel bricks as an appropriate small business venture

The five potential value-added options are discussed below.

Wood-Plastic Composites

Wood-plastic composites (WPC) are products made of a combination of wood fiber and thermoplastics such as polyethylene and polypropylene (as virgin or recycled material). WPCs are still relatively new materials in the wood products industry. WPCs are primarily used as wood decking but are also used for railings, fences, landscaping timbers, siding, park outdoor and indoor furniture, molding and trim, and window and doorframes. WPC's were first introduced into the residential decking market in the early 1990's. They are often considered a sustainable material because they can be made using waste woody biomass and recycled plastics.

PJ Woodlands, a company based in Albuquerque, is an example of a company which is currently establishing itself as a manufacturer of WPC. Their WPC product line can reportedly utilize the waste biomass material from a wide range of tree species and all forms of the waste biomass materials: limbs, needles, bark, etc. [43]

A WPC product manufacturing process meets many of the critical attributes for a potential value-added process in the Taos region. As the Altree process is modular, a facility can be designed to add-on production lines as feedstock supply increases or markets for the Altree products ramp up. An Altree WPC production line uses approximately 5,000 BDT per year, and a facility could conceivably begin with one line. The optimal size facility begins at 4 lines (20,000 BDT, which is under the current estimate of available waste biomass in the Taos region) and would employ 48 full-time employees.[44] This does not include employment to acquire and process the waste biomass materials for delivery to the production facility.

As a potential eco-friendly substitute for traditional plywood, both existing and potential markets exist locally, regionally, and beyond into the southwestern and western markets. Transportation to the markets from Taos can be accomplished by truck with transfer to rail in Albuquerque if the market demands.

Siting of a WPC facility could utilize existing warehouse buildings in the Taos region where available. Facilities could also be sited at existing sawmills or product yards (a structure to

[43] Personal communication on 9/13/16 with Tony J. Burger, CEO, PJ Woodlands, Albuquerque, NM.
[44] Based on PJ Woodlands projections.

house the equipment and operations would be necessary) and could utilize residuals from those operations.

Biomass Heating Systems

Biomass thermal heating is an effective use of waste biomass material. Essentially, the wood waste is combusted in a biomass boiler system to produce hot water or steam in a closed loop configuration, which can then be transferred via a simple heat exchange system to either heat water and/or air for space heating. Biomass thermal heating systems are used extensively in Europe and are becoming common in the northeastern U.S.

Biomass heating systems in the Taos region could utilize some of the potential biomass waste material that would be derived from forest hazardous fuels reduction, timber harvest operations, forest restoration and landfill wood waste recovery activities.

Woody biomass is commonly used for facility (residential, commercial, and institutional) heating in three forms: whole logs and/or cordwood, wood chips, and wood pellets. Space and water heating systems are available from small (6,000 Btus/hour) to very large (over 100 million Btus/hour).[45] Biomass systems, particularly small- and mid-size systems. are available off-the-shelf from numerous manufacturers. Larger pellet and wood chip-fired are commercially available from several companies. The larger systems typically require both facility modification and system customization, mainly for integration of the fuel storage, handling, and conveying systems.

Biomass systems require more operator interaction than other renewable energy systems such as solar and wind. This includes ordering and delivering fuel, removing ash, and maintaining moving parts (e.g., fuel conveyors). Overall, however, biomass heating systems typically only require a few to several minutes of attention each day. Compared to most other renewable energy options currently available, biomass has the advantage of dispatchability, meaning it is controllable and available when needed, similar to fossil fuel heating systems.

A biomass thermal heating system can generally be coupled with existing gas or propane fired heating system, whereby the existing system is utilized as potential backup or to supplement the biomass heat requirements during peak demand. This ensures that a redundant system for heating is available at all times.

Wood waste biomass heating systems can be designed to be fairly automated. Wood fuel can be fed to the boiler system automatically from a fuel hopper. However, there is some labor required to supply the hopper with wood fuel. The biomass boiler system itself can be centralized with the hot water or steam fed into distribution lines that can supply heat to individual heat exchangers associated with individual space heating or hot water units. This type of configuration is often referred to as district heating.

As previously mentioned, the presence of natural gas in the Taos region does have a dampening effect on the use of biomass-fired heating for space and hot water heating. Nonetheless, as

[45] The range of BTUs in a pound of forest-sourced biomass wood waste is approximately 7,500 to 8,000 (or 15 to 16 million per BDT).

biomass heating in price per Btu is still slightly lower than natural gas, there are numerous commercial and institutional/governmental buildings in and around the town of Taos that could investigate the use of biomass fuel and heat systems as a potential retrofit (particularly for heating systems that due to age are candidates for replacement) or in new construction.

Commercial and institutional/governmental buildings and facilities in other areas of the Taos TSA that are not currently using natural gas may use propane, or electricity, instead. Such facilities are economically better suited for biomass heating system retrofitting due to the higher cost of propane over natural gas. For comparison:

- Propane at $1.99 gallon[46] has an energy content of 92,500 Btu/gallon and a heating system efficiency of 72% would result in a price per energy unit of $29.79/MMBtu;
- Retail electricity for commercial and institutional facilities in New Mexico average 9.32 cents/kilowatt hour [47] has an energy content of 3,412 Btu/kilowatt hour and a heating system efficiency of 98% would result in a price per energy unit of $27.87/MMBtu;
- Woody biomass derived from forest hazardous fuels reduction, timber harvest operations and forest restoration activities, and delivered in the $50/BDT range, with an energy content of 7,500 Btu/dry pound and a heating system efficiency of 58% would result in a price per energy unit of $5.74/MMBtu.

As can be seen from above, woody biomass heating systems can certainly be a lower cost form of space and water heating. However, the presence of natural gas in Taos, with most (or nearly all) buildings and facilities likely using it, biomass-fired heating systems for commercial and institutional/governmental buildings would likely have to be located in other areas of the Taos TSA where propane and electricity are used for space and water heating systems.

New employment opportunities from a biomass thermal project is primarily related to the collection, processing, and transportation of the woody biomass feedstock. Generally, personnel that already operate existing heating systems at facilities can operate the biomass heating system.

TSS has identified a potential large facility in the Taos region that could be a good candidate for biomass heating and has also made a site visit. Also identified as a potential candidate is the Southern Methodist University, Fort Burgwin campus (SMU-in-Taos) , which is located about six miles south of Taos and does not have access to natural gas.

Mine Reclamation

Wood chips can be used in the reclamation of abandoned and/or closed mining sites where large concentrations of mine tailings are located. The use of wood chips, combined with biosolids from wastewater treatment facilities, has been used reclaim tailings at molybdenum mines in central Colorado. The combination of these materials, blended in a composting arrangement, creates a soil like footing for vegetation, which significantly aids in the potential cost effective reclamation of large mining sites.

[46] Price of average gallon of propane in New Mexico, see https://www.nmgco.com/gas_calculator.aspx
[47] See http://www.electricitylocal.com/states/new-mexico/

Within the Taos TSA, there is a former molybdenum mine site that requires extensive reclamation and remediation. According to the New Mexico Environment Department, Chevron Questa Mine efforts are including the use of biosolids combined with compost and other material (possibly wood chips) on the mine tailings.[48] However, communication with the Chevron Environmental Management Company revealed that although the use of wood chips were considered at one time, they have been removed from future consideration based on initial testing.[49]

The use of wood chips for mine reclamation would have met some of the critical attributes. In regards to minimum economic scale, it is unknown the amount of wood chips that would have been needed. It is known that this use would likely have been on a temporary nature as once the mine tailings were reclaimed with vegetation, wood chips would no longer be needed. This is based on other large mine reclamation projects in the west, and the tailings reclamation schedule for the Questa Mine.[50]

Job creation would generally be limited to the collection, processing, and transportation of the woody biomass feedstock supply used for reclamation activities.

Pyrolysis Production of Biochar

Pyrolysis production of biochar is the decomposition of woody biomass by heating in an oxygen-free, or oxygen limited, environment. This decomposition results in the production of three phases: gas (known as product gas or syngas), condensable vapors (which forms bio-oil), and solid char (also known as biochar). The yield of biochar from a given unit of woody biomass material ranges from 20% up to 50% depending on the technique and equipment used. Generally, fast pyrolysis is preferred over slow pyrolysis due to better biochar quality and significantly less adverse emissions.

Biochar could be produced in the Taos region using biomass waste material that would be derived from forest hazardous fuels reduction, timber harvest operations, forest restoration and landfill wood waste recovery activities. There are numerous potential uses for biochar, such as:

- Soil amendment and soil conditioning
- Compost additive
- Air filtering and decontamination
- Soil additive for soil remediation
- Treating pond and lake water (through adsorption of pesticides and herbicides)
- Increasing biogas production in anaerobic digestion
- Treatment of domestic and industrial wastewater
- Environmental remediation such as acid mine discharge treatment

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[48] Personal communication with Joseph Fox, New Mexico Environment Department, September 13, 2016.
[49] Personal communication with Michael Coates, Questa Project Coordinator, Chevron Environmental Management Company, September 15, 2016.
[50] USEPA, Region 6, Record of Decision, Molycorp, Inc., Questa, NM, December 20, 2010.

- Humates additive[51]

The biochar marketplace is considered by many in the industry as 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 credible studies are accumulating in the literature 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, as lenders and equity partners are generally looking for longer term offtake contracts. 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.

Currently there is continuing evaluation of biochar pyrolysis and use of biochar in combination with green waste composting in the Albuquerque area, among other uses such as Humates additive and wastewater treatment.[52] The use as an additive to humates from regional humate mines is important, as the humate product can use the fines from the biochar pyrolysis process. Adelanto Consulting (Albuquerque, NM) and TNC are partnering with Sandoval County to develop a biomass utilization facility that is capable of processing up to 80,000 BDT of woody biomass material into biochar.[53] This team has submitted an application to the USDA for grant funding for engineering feasibility, marketing, and implementation planning. Such a project, if successful, could be a model for something similar in the Taos region.

The water and wastewater filtration market for biochar in New Mexico and the southwest in general holds promise as well. However, research is needed as to the number of facilities, the amount of water or wastewater that could be processed using biochar, and the amount and cost of activated carbon now currently used which could be offset by potentially lower cost biochar.

From an employment perspective, biochar production is attractive as it could: 1) provide livable wages to its workers, 2) provide potential year-round employment, and 3) create potential partnerships with local and regional industries (i.e., composting firms, nurseries, and co-location with existing wood and lumber production facilities). The collection, processing, and transportation of the woody biomass feedstock, along with the manufacturing of the fuel bricks, will create jobs. It can be estimated that the use of 8,000 BDT per year of woody biomass feedstock could create 5 to 7 jobs (4 to 5 collecting, processing, and transporting the feedstock, and 2 to 3 operating the biochar production system).

<u>Fuel Bricks</u>

Wood fuel bricks can be considered a potential added value utilization opportunity for the Taos region using biomass waste material that would be derived from forest hazardous fuels reduction, timber harvest operations, forest restoration and landfill wood waste recovery activities. A

[51] Humates are a highly compressed, natural organic humus, applied to soil to enhance plant growth. Humate is particularly common in New Mexico and occurs with coal deposits.
[52] Personal communication with Ed Singleton, Adelante Consulting, Albuquerque, NM, September 30, 2016.
[53] Ibid, November 19, 2016.

woody biomass briquetter, such as those offered by RUF Briquetting Systems,[54] can convert loose woody waste material into uniform-sized briquettes that are easy to store and transport to market.

The RUF systems come in several sizes, with the most commonly sold in the 1,350 pounds per hour throughput (RUF-600) and 2,400 pounds per hour throughput (RUF-1100). The RUF-600 is $141,580 FOB Cleveland, OH, and the RUF-1100 is $235,670.[55] Both units can be further configured to be transportable to field operations. Using a standard work week of 40 hours, a RUF-600 could utilize approximately 1,350 tons per year of woody biomass (250 days x 8 hours x 1,350 pounds/hour ÷ 2,000 lbs/ton).

The wood fuel bricks are created by the RUF briquetter basically by hydraulic pressure. Woody waste biomass (including bark, needles, sawdust, etc.), which has been ground or chipped to reduce the woody biomass to 2-inch minus or less, are placed into a hopper on the briquetter. The biomass materials are then fed into the hydraulic press where the high pressure of the press (up to 24,000 pounds per square inch) produces the briquettes which have cross sections measuring 6 x 2.4 inches and 10 x 4 inches. The length of the briquettes can be set as desired.

Results show that this briquetting system increases the volumetric energy density of chipped biomass by 250% or more, producing briquettes with an average density of 45 to 60-plus 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. This configuration of biomass materials (chipped and sawdust) would be ideal with a briquetter co-located at an existing sawmill.

TSS has interviewed a company using a briquetting machine for use with forest slash in Arizona.[56] The operator uses the portable RUF Briquetting Systems[57] RUF- 600 directly in the forest environment sourcing pinyon-juniper and other wood species, along with the 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 in-forest projects. Marketing of the briquette product from this operator has been principally by "word of mouth" but the briquettes are reportedly selling at Whole Foods, and even in a Taos wood stove store. The operator was not forthcoming at this time as to his cost to produce the briquettes he is currently selling. However, in discussions with RUF Briquetting Systems,[58] they believe that the briquettes could be manufactured and sold at a wholesale cost of about $165 per ton delivered. Currently, wood briquettes are retailing on a national average range of $250 to $275 per ton, with cord wood in the Taos area currently selling for $200 cord (unstacked) for mixed fir/pine. These price points are significant since the

[54] https://www.ruf-briquetter.com
[55] Jay Petre, RUF Briquetting Systems, (681) 318-8888, JayP@ruf-briquetter.com
[56] Gary Snyder, Pradera Madera, Lakeside AZ, (928) 606-3138, pradamadera@gmailcom
[57] RUF Briquetting Systems, Elyria, OH, https://www.ruf-briquetter.com/briquette-press
[58] Jay Petre, RUF Briquetting Systems, (681) 318-8888, JayP@ruf-briquetter.com

briquettes are densified wood, and they can cost less than cordwood on a heating value basis. Cord wood heating value is approximately 4,500 BTU/lb of green wood (Ponderosa pine), whereas briquetted wood being densified is approximately 8,000 BTU/lb.[59]

Wood waste briquetting could meet some of the critical attributes. In regards 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-based wood waste. Based upon discussions with the field operator, the briquetting unit can use most of the wood waste composition; however, large wood particles (4-inch or greater) could cause issues during the briquetting process.

Wood-fired residential heating is a relatively large and robust market in the Taos region (and northern New Mexico in general). However, wood briquettes could impact the cord wood markets by substituting briquettes for cordwood. Transportation to markets could also be lower than cordwood due to the densification factor in briquetted wood waste. While there are synergies with co-location briquetting systems at existing sawmill or product yards, again there is the specter of competition with the existing firewood market.

In regards to employment, the collection, processing, and transportation of the woody biomass feedstock, along with the manufacturing of the fuel bricks, will create jobs. For a fuel brick mobile unit (like the RUF units), this could add 3 to 6 jobs per operating unit.

[59] Ibid.

RECOMMENDATIONS AND NEXT STEPS

Value-Added Opportunities

Due to the currently very limited value-added markets for woody biomass material generated as a byproduct of forest fuels treatment activities in the Taos region, most of the fuels treatment operations are in-forest processing (chipping) biomass and leaving it on site or piling and burning the biomass materials. Commercial roundwood is removed as sawlogs, firewood, vigas, and latillas, with residuals (limbs, tops, small stems) piled and burned or chipped and scattered. These residuals have the potential to be utilized as feedstock for value-added processes.

Discussions with current woody biomass facility owners/operators (sawmills, landfills, transfer stations, etc.), foresters, and potential users of the waste woody biomass indicated that if a ready market for biomass existed, with values high enough to cover most of the processing and transport costs, significant waste biomass volume would be diverted away from current business-as-usual activities (e.g., chip/pile and burn/landfill disposal). Results of these discussions confirm that there are opportunities to add value to forest biomass generated as a byproduct of forest fuels treatment, forest restoration, and landfill wood waste recovery activities in the Taos region.

In coordination with TNC, TSS identified five potential value-added options for the Taos region. These five options were discussed in detail above. As part of the TSS scope of work, three of these options are considered candidates for Phase II analysis. These are:

- Wood/plastic composite board
- Biomass heating of a large facility
- Fuel bricks

All three options and their potential implementation in the Taos region will benefit from a Phase II analysis. That analysis will take a "deep-dive" into the economic and technical feasibility of these three options.

Local Partners to Consider for Phase II

- PJ Woodlands and the Altree product – PJ Woodlands, LLC (Albuquerque, NM), Tony Burger, Managing Member, burgertjb@icloud.com, (505) 242-674 (office), (505) 417-3112 (mobile)
- Southern Methodist University (SMU-in-Taos), Fort Burgwin, NM, Greg Medina, (575) 721-1243
- Pradera Madera (fuel bricks), Gary Snyder, (928) 606-3138

Community Outreach

In the course of this investigation, TSS worked in concert with TNC to conduct two community workshops in Taos. The initial workshop, held June 8, provided interested community members and stakeholders with an overview of the Rio Grande Water Fund objectives and an overview of the wood waste feedstock utilization assessment. The second workshop, held August 25, provided an opportunity for TSS and TNC to review initial feedstock supply findings and discuss the range of value-added utilization options. Notes for both meetings can be found in the Appendix.

TSS recommends that continued dialogue with the community is critical to success. Local businesses, residents, land managers and agency staff should have the opportunity to weigh in on the value-added technologies targeted for possible deployment. As this report is finalized, an executive summary document should be posted on the TNC New Mexico website.

Fuels Treatment/Restoration Demonstrations

Forest and rangeland restoration activities now conducted within the greater Taos region are typically conducted using hand crews, with most of the wood biomass produced left on site. If an active forest biomass utilization sector were to be established in the region, a vibrant supply chain would need to be developed. TSS recommends consideration of a series of fuels treatment/restoration trials that would facilitate demonstration of the latest harvest, collection, processing and transport technologies. These demonstrations would allow local land managers and contractors to view conventional and innovative equipment up close. Site conditions, pre and post treatment, could be monitored to analyze site impacts (e.g., soils, vegetation, fire behavior) and cost effectiveness/efficiency.

New Mexico Renewable Portfolio Standard

In March 2004, New Mexico's governor signed into law the Renewable Energy Act (S.B. 43) creating a renewable portfolio standard for the state of New Mexico. By 2020, the investor owned utilities operating within the state are required to generate 20% of total retail power sales from renewable energy resources, and rural electric cooperatives are required to generate 10% of total retail sales from renewable energy resources.

In August 2007 the NM Public Regulation Commission issued an order and rules requiring that investor owned utilities meet the 20% RPS through a "fully diversified renewable energy portfolio" that includes no less than 30% wind energy and 20% solar power. TSS recommends that the TNC start a conversation with the Public Regulation Commission to require a biomass power set aside of up to 20% of the existing RPS.

National Renewable Fuels Standard

The 2007 Energy Independence and Security Act (EISA) updated the national renewable fuels standard such that forest biomass collected from federally managed lands is not considered renewable. The concern at the time this federal legislation was signed into law was that the harvest of forest biomass from federal lands for the production of advance biofuels (e.g., renewable diesel, renewable ethanol) could result in the over harvesting of federal forests.

In recent years there has been an effort to create federal legislation that facilitates a 10 year pilot project that would accommodate five pilot projects that source forest feedstock from federal lands.[60] The pilot project would include protocols to monitor impacts to forest and range resources (e.g., wildlife habitat, soils, fire behavior) while allowing forest biomass from federal lands to qualify as renewable. TSS suggests that TNC consider supporting this initiative.

[60] Lake County Resources Initiative.

Appendix A. June 8, 2016 Community Meeting Notes

WHAT TO DO WITH EXCESS TREES AND BRUSH REMOVED DURING WATERSHED RESTORATION ACTIVITIES

Juan I. Gonzales Agricultural Center, 202 Chamisa Road, Taos NM
The Nature Conservancy and New Mexico Forest Industry Association

June 8, 2016

Meeting Notes – Feedback from Meeting Attendees

Summarized below are notes taken by TSS (Gary and Tad) during the Community Meeting.

- Interested stakeholder from Penasco would like to better understand how grant funding is distributed so that communities as risk (such as Penasco) near important watersheds can ramp up fuels treatment activities.

- Village of Angel Fire representatives provided an overview of the current community capacity to pro-actively treat fuels. AF has invested in two slash trucks that collect slash, small stems and brush placed roadside by AF residents. This material is transported to the local transfer station and processed on site using a grinder. Processed material is made available (at no charge) and is typically utilized as landscape cover or compost. Creating more chips than they can possibly utilize locally. Would like to provide this material to support the Questa mine restoration (dispersed as cover to mitigate erosion). Working with private landowners (about 20,000 acres total) in the area to conduct "fuel modification" (alternative term to "forest thinning").

- Taos area sawmill owner concerned that USFS is slow to respond to local markets – short term and long term. Example is the market (typically in the spring) for aspen logs.

- Discussion of fire risk (severity) as a tool to prioritize fuels treatment project selection and funding. Concern expressed that WUI treatments may be compromised by not treating forest and woodlands located upland (outside of the WUI treatments).

- Some discussions regarding development of a dairy or feedlot that could generate manure for production of soil amendments (when blended with chips from forest/woodland treatments).

- Some discussion of fuel models (fire severity) and local advocacy driving allocation of funding for treatment of high risk landscapes.

- Observation that about 15 wood mizer (small-scale sawmills) are currently operating in the region, utilizing locally produced sawlogs.

- Acres treated need to ramp up to accommodate existing and new utilization.

- Any new enterprises using forest or woodland generated material should not compete with local (existing) businesses.

- Recommendation that the state building codes accommodate lumber produced by area sawmills – and not require certification (grade stamps) for use in construction.

- Fuel breaks bordering wilderness areas will help mitigate wildfire impacts from fires that start in the wilderness. Or alternatively – USFS policy should allow for fuels treatment or fire suppression with wilderness located adjacent to communities at risk.

- Priorities should dictate that increased funding be allocated to landscape-scale fuels treatment activities in the forest or woodlands.

- Carson NF Land Management Plan up for review. Opportunity for communities to weigh in on land management direction and priorities.

Appendix B. August 15, 2016 Community Meeting Notes

WHAT TO DO WITH EXCESS TREES AND BRUSH REMOVED DURING WATERSHED RESTORATION ACTIVITIES

Juan I. Gonzales Agricultural Center, 202 Chamisa Road, Taos NM
The Nature Conservancy and New Mexico Forest Industry Association

Second Community Meeting
August 25, 2016
6:00 to 7:30 PM

Meeting Notes – Feedback from Meeting Attendees

Summarized below are notes taken by Hanna Miller, Laura McCarthy, and TSS during the 8/25 Community Meeting.

- Laura McCarthy began with background and an update on the Rio Grande Water Fund recent activities such as local and regional hazardous fuels removal and construction of firebreak projects in various communities as ongoing activities for those projects to happen (archaeological/culture resources clearance, stand examination, contracting, etc.)
- Forest restoration activities in the Taos area were discussed. McGaffey Ridge discussed as an example.
- The current robust markets for Taos area stem wood and roundwood was discussed. A point was made that the added-value utilization of biomass wood waste should not be set up to directly compete with existing northern New Mexico wood product businesses.
- Fred Tornatore of TSS began his Power Point presentation[61] of initial findings of the wood utilization assessment for the Taos Target Study Area (TSA). This woody biomass resource assessment consisted of the biomass feedstock supply analysis, biomass supply competition analysis, and the regional biomass feedstock analysis. Included in the analyses was the projected potential price per bone dry ton of the various sources of available woody biomass. TSS presented the following summary of the supply of potential biomass availability in the Taos TSA:
  - Potentially available – 57,721 BDT, total amount produced annually
  - Technically available – 27,897 BDT, amount available annually taking into account physical constraints (steep slopes, transportation, etc.)
  - Economically available – 27,876 BDT, amount available annually taking into account competition for the wood waste (there is almost no current use of wood waste from forest thinning and restoration activities in the Taos TSA).

  Given this relatively small amount of available wood waste, there will not be massive

[61] Power Point slides can be accessed at http://tssconsultants.com/wp-content/uploads/2016/11/Wood-Waste-Util-Assess-Second-Meeting-PPT-20160819.pdf

projects with this amount. Discussion ensued that there should be more wood waste available if only the Forest Service would increase forest thinning as is desperately needed in the Taos region. It was remarked that the area is at the beginning of potential scale up of such activities. Discussion ensued with many comments on how this scale up might occur, and how this increased amount of wood waste would not end up being just piled and burned (the current option).

- The estimated costs of the forest-sourced wood waste were presented. The estimated cost for forest-sourced wood waste feedstock collection, processing, and transporting averages from $42.50 to $49.38 per BDT delivered. Transportation distance was pegged at 30 miles one way.
- The potential for electricity generation using forest sourced wood waste was discussed. It was considered not to be a good option as the retail price of electricity is very low in New Mexico. With the average feedstock cost of $40 to $50 this would translate to 4 to 5 cents a kilowatt hour just for fuel for the power plant, which is likely more than the cost of producing electricity currently in New Mexico and what the utilities would want to pay for biomass power.

  California's BioMAT (Bioenergy Market Adjustment Tariff) program was discussed as a model for New Mexico for trying to bring in the non-monetized societal and environmental benefits of biomass power. There was interest all around that New Mexico needs to look into a BioMAT type program.
- The use of regional wood waste as a substitute for natural gas or propane for space and water heating was discussed. Wood compared to propane is particularly cost effective, but very little when compared to the use of natural gas, but there are additional social, environmental, and economic benefits in using biomass over fossil fuels. TSS met with Taos Ski Valley, who expressed interest in examining the potential to use local and regional biomass for space and water heating (with leaving their natural gas system in place as backup). Further analysis is needed to determine the benefits of such a system at TSV and could be part of the Phase II analysis of value-added biomass utilization in the Taos region.
- TSS also has heard that the massive reclamation and soil/water remediation activities at the Chevron-owned Questa Mine might be using a combination of bio-solids (from wastewater treatment facilities) and wood chips. It could be a considerable amount of wood chips over several years. TSS will track down this particular utilization option.
- A discussion ensued about what TSS has learned regarding potential near to medium term uses of wood waste. Five options were discussed:
  - Biomass heating at TSV
  - Wood/plastic composite board (via the Altree process – see http://www.altree.com)
  - Questa mine reclamation and remediation
  - Conversion of other building and facilities in the Taos region to biomass space and water heating, particularly those currently using propane

- Potential production of biochar (for soil/compost amendment and water filtration)

- Questions were asked about why was Taos selected as the center of the TSA. Might other northern New Mexico communities be in a better “sweet spot” for value-added utilization. The use of the TSS report was also discussed as to what will be the fate of the report and what have other communities done with similar studies prepared by TSS. It was explained that several of the studies have left to the planning and development of value-added products. The Calaveras County (California Sierra Nevada region) value-added project is currently under development for power generation (under California’s BioMAT), small sawmill, fire wood drying, greenhousing (using biomass for heating), and lumber kilns.

- The use of forest-source wood waste for slope stabilization, erosion control, and better water (as precipitation) infiltration into the region’ soils was discussed as an important option as well as for reclamation of old log skidding trails and protection and enhancement of arroyos. Currently this is being done in the Taos region and monitoring of this on-site utilization is needed to further determine the efficacy of this use of wood waste.

- The emerging market of biochar as soil/compost amendment and water/wastewater filtration was brought up. TSS opined that whereas it looks like a promising market (conversion of wood waste to biochar), the biochar market is in its infancy and where ultimately prices for biochar end up are still a subject of conjecture. However, it is worth exploring as a value-added use.

- Discussion came back around to the use of the biomass wood waste for space and water heating. Several participants continued to talk about local building. TSS further discussed some of the economic barriers to retrofitting facilities. A list of candidate facilities would have to be generated, with each candidate individually evaluated. Again, propane using facilities, as well as new, as yet built, facilities were deemed more appropriate for analysis than natural gas fired facilities.

- Mention was made of a large proposed commercial wood pellet in the Las Vegas (NM) area, sourcing wood from 100-mile radius.

- The ability of the forest to store carbon and the carbon neutrality of biomass wood waste utilization was discussed. Somehow this ability needs to be brought into the valued-added equation to further increase economic viability.

- Meeting adjourned just after 8 PM.