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QUINAULT INDIAN NATION
BIOMASS FEASIBILITY STUDY

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ABBREVIATIONS/ACRONYMS

The abbreviations and acronyms utilized in this report include:

Organizations

BIA	Bureau of Indian Affairs
ColPac	Columbia Pacific Resource Conservation and Economic Development District
QIN	Quinault Indian Nation
TSS	TSS Consultants
USFS	United States Forest Service

Other Terms

BDT	Bone Dry Ton(s)
Btu	British thermal unit
CHP	Combined Heat and Power
GIS	Geographic Information System
GT	Green Ton
HHV	Higher Heating Value
MBF	Thousand Board Feet
MMBF	Million Board Feet
MW	Megawatt (Electric)
MMBtu	Million British Thermal Units
TSA	Target Study Area

INTRODUCTION

The Columbia-Pacific Resource Conservation and Economic Development District (ColPac) has retained TSS Consultants (TSS) to provide technical assistance in evaluating the feasibility for development of a woody biomass thermal energy project and prospective value-added utilization alternatives for the Quinault Indian Nation (QIN) to be located at Taholah, Washington.

The facility would use woody biomass from forest operations conducted on the QIN reservation as the primary feedstock. The QIN reservation has over 207,000 acres of highly productive forestland that is managed sustainably under the guidance of an Integrated Resource Management Plan (IRMP). The thermal energy facility would supply distributed heat to public buildings proposed for relocation, as well as existing buildings near the proposed relocation site. These new facilities include a school (currently under construction), community center and the emergency services/justice center.

TSS is tasked with assessing the biomass resource volumes and delivered cost estimates from QIN Reservation forest operations, reviewing and conducting financial evaluation of selected thermal energy technologies, and analyzing prospective value-added enterprises for QIN to consider for utilizing biomass material not utilized by the thermal energy facility.

SCOPE OF WORK

The tasks that TSS Consultants (TSS) has implemented in support of this feasibility study are detailed below. TSS utilized relevant data and information from existing assessments and studies conducted in the Olympic Peninsula region. For example, TSS and the University of Washington have retained by the Washington Department of Natural Resources to implement a statewide assessment of biomass resource availability. This report is in the final stages of review and completion. Data from this effort was used to support this biomass utilization feasibility study on the QIN Reservation.

Task 1. Pre-Work Conference

Convene a meeting with ColPac and Tribal staff. Review project need, approach and implementation schedule for the feasibility study. Confirm primary ColPac and Tribal contacts and project management team members. Review availability of existing studies and data. Confirm target study area for sourcing of woody biomass materials (Figure 1 highlights the QIN Reservation and a draft target study area). Review existing and potential thermal energy technologies that are commercially available and cost effective. Conduct a review of potential siting opportunities on the QIN Reservation (including the 110 acre target site).

Figure 1. Draft Target Study Area – QIN Reservation

Task 2. Project Description

TSS will draft an introduction section detailing the proposed project, confirming the goals and objectives of ColPac and QIN, as well as determining the appropriate target study area for the biomass fuel availability analysis. This draft document will review current utilization of woody biomass material from forest operations, including business practices, alternative uses, and a brief discussion of thermal energy technology employed for distributed heat. This draft document will be delivered to ColPac and Tribal staff for review. (The Project Description is included in this report as Appendix B.)

Task 3. Biomass Feedstock Availability and Cost Analysis

Conduct a review of potential woody biomass feedstocks available from forest operations conducted on the QIN Reservation, including timber harvest, pre-commercial thinning and fuels treatment activities. Existing forest inventory data and forest operations plans will be used to forecast the volumes and types of byproducts that are available on a long-term sustainable basis using best practices.

TSS will analyze availability of woody biomass material including:

- Raw material/woody biomass from forest operations:
  - Timber harvest operations;
  - Fuels treatment/forest restoration projects;

    - Timber stand improvement projects;
- Raw material/woody biomass from urban wood waste (construction/demolition wood, pallets, tree trimmings).

The costs associated with collection, processing and transport of these feedstocks will be analyzed. Findings from this analysis will be used to provide a forecast of biomass material meeting feedstock specifications that is available annually from the target study area. This forecast and the methodologies used (to generate this forecast) will be delivered in a draft document to ColPac and Tribal staff for review.

Task 3. Augmented SOW Biomass Feedstock Availability and Cost Analysis

In order for QIN staff to effectively analyze the economic costs to recover, process and transport timber harvest residuals from operations conducted on the Reservation, a financial proforma (using excel workbook format) will be generated. This workbook will estimate (calculate) prospective biomass volume from various forest operations within the Reservation, on-board truck costs (including processing material into suitable product per market specifications) and delivered costs. Cost centers and variables considered will include:

- Forest operations type (timber harvest, stand improvement)
- Harvest prescription
- Yarding specifications
- Biomass recovery constraints (i.e., distance from road machinery allowed to collect material)
- Equipment and transport access
- Diesel fuel pricing
- Distance hauled (on and off pavement)
- Equipment costs ($/hour)
    - Excavator
    - Flail/chipper (to meet pulp chip or fuel pellet feedstock specifications)
    - Grinder
    - Truck/trailer
    - Service truck
    - Crew truck
    - Potential shutdowns for weather (rains, flooding, freezing, etc.)

The biomass volume and cost model example and the User Manual are included in Appendix C.

Fuel samples will be secured for testing (heat value, moisture content, ash content) with the results being utilized to provide equipment vendors (e.g., Messersmith and Skanden) with a characterization of locally available fuel feedstocks. Fuel sample testing results will also facilitate an optimized fuel blend forecast to help assure efficient thermal energy operations at Taholah.

Task 4. Key Environmental Issues/Opportunities

Utilizing findings and results from implementation of Tasks 2 and 3, TSS will conduct a review of key environmental impacts that may result due to development and operation of a biomass fired thermal energy facility sited in Taholah. Key issues and opportunities to be reviewed include:

- Impacts to the Tribal community:
    - Job training and employment
    - Air quality improvement
    - Cultural resources
- Tribal forest resources:
    - Utilization of forest biomass that is currently piled and burned
    - Opportunity to treat overstocked stands
- Target site considerations and mitigation:
    - Thermal energy demand
    - Water availability
    - Road access and truck traffic
    - Noise
    - Air emissions
    - Other

Analysis results and the methodologies used will be delivered in a draft document to ColPac and Tribal staff for review.

Task 4. Augmented SOW Key Environmental Issues/Opportunities

There may be an opportunity to create a tribal enterprise that recovers, processes and transports processed forest biomass material to a thermal energy facility at Taholah and to value-added markets in the greater Aberdeen/Grays Harbor region. TSS will conduct an analysis to confirm the total capital costs required to start up and manage a tribal enterprise that recovers forest biomass for value-added markets. The recent closure of the Grays Harbor Paper facility has changed the local market demand for both hog fuel and pulp chips. TSS will conduct a market review to confirm local demand and market prices for both hog fuel and pulp chips. As a result of this analysis, observations and recommendations will be provided that defines next steps for the QIN to consider.

TSS will conduct an analysis to better assess the opportunities to service value-added markets focused on the pulp/paper chip markets and a fuel pellet operation located on the Reservation. The capital costs to site a commercial-scale fuel pellet facility on the Reservation will be reviewed, as well as an overview of opportunities to market fuel pellets in the region. As a result of this analysis, observations and recommendations will be provided that define next steps for the QIN to consider. A list of potential grant funding sources is included as Appendix A.

Task 5. Site Review and Selection

Results of Task 4 will be utilized to conduct a site review to confirm the optimized location for a thermal energy facility on the QIN Reservation. A site review of two potential locations for the thermal energy facility will be conducted. Site attributes listed below will be considered:

- Land Use Zoning
- Transportation, Routes, and Corridors
- Public Health and Safety
- Water Supply Resources
- Geology/Soils
- Cultural Resources
- Potential Co-location Opportunities

TSS will interface with Tribal staff regarding pre-construction requirements (i.e., building permits and land use entitlements) and studies that may be required for the construction of a thermal energy facility. Regulatory guidance will also be obtained from the U.S. Environmental Protection Agency (Region 10) where appropriate and applicable. TSS will deliver draft results of the site review findings for Tribal staff review for selection of a preferred site.

Task 6. Technology Selection and Financial Analysis

Utilizing findings from Tasks 2 through 5, conduct a thermal energy technology review to match feedstock availability/characteristics, local environmental permitting requirements, site attributes and thermal load forecast (for all three buildings) with existing, commercially-proven technologies. Selection of a technology that optimizes utilization of forest-sourced biomass feedstocks while generating cost effective thermal energy that meets environmental regulations is key to project success. The top two technologies considered will be presented to ColPac and Tribal staff with recommendations.

Once the preferred technology is selected by the Tribal staff, the selected technology vendor will be contacted and specific cost estimates/details will be secured for the following:

- Equipment capital costs
- Equipment installation costs
- Annual operations and maintenance costs
- Training required for operations personnel
- Site requirements
- Infrastructure requirements
- Estimated raw material supply (product and volume) needs
- Limiting factors

TSS will provide data and information relative to the prospective economic impact of such a facility to QIN, as well as employment opportunities related to fuel supply and facility operation. This review will include a brief description of preferred experience/attributes/training necessary for such employment opportunities. Data provided by the technology vendor will be utilized to conduct a financial analysis that provides the cost of thermal energy. Financial analysis results (e.g., $/million Btu, payback period, operations and maintenance costs) will be delivered in draft format to ColPac and Tribal staff for review.

Task 6. Augmented SOW Technology Selection and Financial Analysis

In order to take advantage of existing experience and knowledge regarding thermal energy installations currently utilizing forest biomass, interviews with two owner/operators will be conducted with entities (e.g., school district staff) that have facilities that are similar to the facility considered for Taholah. It is anticipated that these entities should be able to provide information regarding:

- Lessons learned
- Service life of equipment
- Observations regarding different fuel mixes
- Operating costs
- Training of personnel
- Overall costs to own/operate

TSS will deliver the results of these interviews.

Supplement the existing financial proforma for the Messersmith and Skanden thermal energy facilities to show thermal energy cost sensitivities as a function of delivered biomass fuel costs.

Task 7. Generate Feasibility Study Report

Based upon information, findings and ColPac /Tribal staff input assimilated in Tasks 2 through 6, generate a final report document. The final report will be written with the target audience (Tribal Council members and staff, informed members of the public and private sector, financial institution staff, and associated agency staff) in mind.

The feasibility study report will include (but not necessarily be limited to) the following sections:

- Title Page
- Table of Contents
- List of Tables/Figures
- Introduction
- Key Findings
  - Biomass Resource Availability/Pricing
  - Top-Ranked Site Location
  - Top-Ranked Technology
- Environmental Setting and Project Area
- Biomass Resource Availability and Delivered Cost
- Preferred Technology
- Financial Analysis

- Conclusions
- Recommendations and Next Steps to Consider
- Grant Funding Resources
- Appendices

An electronic version of the report will be made available to facilitate distribution. The report will be delivered no later than September 1, 2011. The augmented Scope of Work allowed extension of report completion to January 2012. Present report findings to ColPac and Tribal staff.

Task 8. Project Management

During the implementation phase of this feasibility study, it will be very important that TSS, ColPac and Tribal staff communicate regularly. In the course of conducting feasibility studies, a key lesson learned is that client/contractor communication and coordination is paramount to assure successful analysis and delivery of work product. TSS will provide project management services including:

- Monthly progress reports.
- Regular communication and coordination via meetings (including conference calls) with ColPac and Tribal staff.

KEY FINDINGS

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

Biomass Resource Availability and Pricing

The QIN Reservation consists primarily of commercial forestland. An estimated 196,700 of the total 207,300 is comprised of forested cover (95% of the reservation). Woody biomass material from forest operations within the reservation is to be the primary feedstock source for the thermal energy facility. Table 1 provides an overview of potentially and practically available woody biomass volumes from forest operations conducted by either QIN or the Bureau of Indian Affairs (BIA). The standard unit of measure for woody biomass is bone dry ton (BDT).[1]

[1]One bone dry ton is the nominal equivalent of 2,000 pounds of dry wood fiber (no moisture content.

Table 1. Biomass Material Potentially and Practically Available on the QIN Reservation

LAND MANAGER	POTENTIALLY AVAILABLE BDT/YEAR	PRACTICALLY AVAILABLE BDT/YEAR
QIN	13,100	5,460
BIA	20,650	8,600
TOTALS	**33,750**	**14,060**

Table 2 summarizes the estimated costs of collection, processing and transport to deliver biomass material to the Taholah site employing biomass recovery alternative operating models.

Table 2. Biomass Material Collection, Processing and Transport Costs

BIOMASS RECOVERY METHOD	LOW RANGE $/BDT	HIGH RANGE $/BDT
Alternative 1	$32	$52
Alternative 2	$42	$63

Alternative 1 represents biomass recovery from only those harvest units and/or slash piles determined to be easily accessible, minimizing contractor processing and transport costs. Alternative 2 represents complete biomass recovery from within units, including isolated material or units with access challenges.

Feedstock specifications and quality are an important issue for the thermal energy systems as well as value-added biomass utilization enterprises considered. In general, these smaller thermal energy units require consistent feedstock sizing, moisture content (<40%) and are impacted more significantly by contaminants (e.g., dirt) than larger, industrial-scale boilers.

The financial analysis yields large negative Net Present Value (NPV) for 100% QIN equity as well as 50% QIN equity and 50% debt financing. The project is still not economically feasible with a grant for 50% of the project capital, since the Return on Equity (ROE) of 7.7% is less than the acceptable return of 10% to 15% for such projects. If the project could be financed with a 100% grant, it would be very feasible since it would provide a large positive NPV to QIN.

Site Selection

A biomass fueled facility at the TMI Forest Products – Crane Creek Division facility located at Amanda Park was considered as a potential site. TMI Forest Products staff indicated no interest in a biomass utilization facility at the Crane Creek Division plant site. The preferred site for a biomass fueled thermal energy facility was identified as Taholah, providing thermal energy to a proposed new school, community center and emergency services/justice center, as well as existing buildings identified as the QIN Administration Complex and Health Clinic.

Technology Selection

The technology TSS believes is best suited for the Taholah site is direct combustion rather than gasification. Systems such as those produced by Messersmith Manufacturing, Inc. and Skanden are direct combustion systems that are relatively easy to operate. The system employed at the Forks, Washington school is from Messersmith Manufacturing, Inc. TSS recommended the technology produced by Messersmith Manufacturing, Inc. for Taholah based upon the experience of Messersmith with regard to the various types of feedstock used in their units as well as the number of their units currently operating in the western U.S.

Financial Analysis Results

The estimated installed cost for the selected technology based on a quote for the furnace/boiler from Messersmith, including a distribution line to the buildings, lead-in lines to the buildings and building heaters is $1,308,725. The financial analysis indicates that a woody biomass utilization thermal energy project at Taholah is not financially viable without substantive g rant funding for capital costs. If the project could be financed with an 80% grant, it would provide an NPV of $128,331 or 24.7% ROE. With an 80% grant for capital costs, utilizing wood heating as opposed to heating with electricity would yield savings of $78,872 per year.

Value-added Alternatives and Biomass Recovery Opportunities

A number of value-added alternatives are potentially available for utilization of biomass generated as a byproduct of forest operations for QIN. These could include integrating biomass recovery operations into markets currently consuming biomass as feedstock for combined heat and power; densified firewood substitutes such as logs or bricks; small community-scale combined heat and power; or residential fuel pellets.

Residential fuel pellets generally require clean sawmill byproduct as feedstock to maintain low ash levels. Forest slash used as feedstock to produce pellets would exceed market specifications. Feedstock for densified firewood substitutes such as fire logs or bricks could include byproduct from forest operations; however this material would need to be dried to under 15% moisture content, which can be fairly expensive. Again, including needles and leaves in the feedstock increases ash produced upon combustion. The current market for both firewood and the densified firewood substitutes is in decline. A small community scale combined heat and power project using woody biomass feedstock is an expensive proposition, with poor economic returns given current power rates in the Pacific Northwest.

These alternatives, as well as the thermal energy system, all function most effectively using clean feedstock. In fact, chipped rather than grinding woody biomass material is the better feedstock. The problem with acquiring equipment for chipping product to the specifications above is that it would not serve a biomass recovery production operation developed for marketing product to large, industrial boilers (such as those used in the pulp and paper and wood products manufacturing facilities).

The most effective solution for a QIN enterprise focused upon recovery, processing and delivery of woody biomass from forest operations on the reservation would be a commercial-scale operation focused upon production of material suitable for both the thermal energy system as well as larger, industrial boiler operations as the primary alternative market. Unfortunately, feedstock for the larger, industrial boiler is unsuited for the thermal energy system. One potential solution is acquisition of a horizontal grinder with the ability to replace parts used for grinding woody biomass with blades used for chip production.

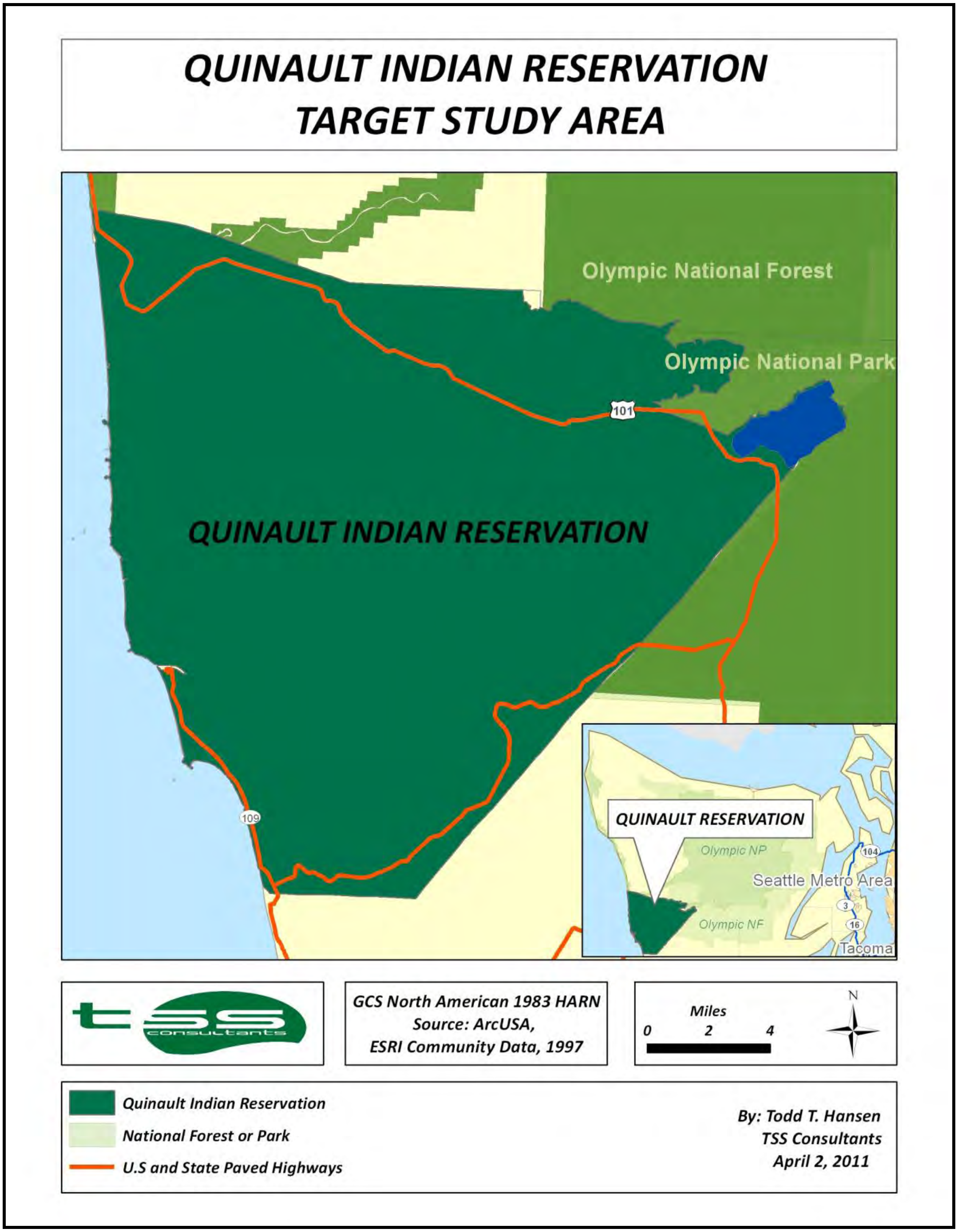
The recent announcement of the potential purchase and reopening of the former Grays Harbor Paper facility would greatly enhance opportunities for a tribal enterprise focused upon recovery of woody material from reservation forestry operations. This would provide a local market for woody biomass material as feedstock for the boiler once the plant is again operational.

BIOMASS AVAILABILITY AND COST ANALYSIS

Target Study Area – Quinault Indian Reservation

The proposed target study area (TSA) for this biomass fuel supply availability analysis is defined by the existing boundaries of the Quinault Indian Reservation. Figure 2 is a map showing the TSA.

Figure 2. Quinault Indian Nation Biomass Fuel Target Study Area



There are several land ownership designations on the reservation. The QIN, the Bureau of Indian Affairs (held in trust), fee-owned allotment (private ownership) and other public ownership represent the primary ownerships. The QIN currently holds title and 100% ownership to an estimated 65,341 gross acres of the total 207,270 mapped[2] acres (from the existing Geographic Information System database) within the reservation. Ownership acres by owner class are shown in Table 3.

Table 3. Quinault Indian Reservation Acres by Ownership

OWNERSHIP	TOTAL ACRES	PERCENT OF TOTAL
Quinault Indian Nation	65,341	32%
Bureau of Indian Affairs (Trust)	116,440	56%
Fee Allotments	25,308	12%
Other	181	<1%
TOTAL	**207,270**	**100%**

The acres in Table 3 reflect total gross acres, unadjusted for rivers, streams, lakes, urban areas, as well as areas of restricted forest operations. Acres by ownership and by operable acres are shown in Table 4. Operable acres reflect adjustment from gross acres (provided in Table 3) for areas consisting of roads, non-forest, designated as non-operable by the Forest Management Plan, the North Boundary Conservation Easement Area, and QIN designated preserves. Operable acres reflect areas suitable for conventional forest management activities.

Table 4. Quinault Indian Reservation Operable Acres by Ownership

OWNERSHIP	OPERABLE ACRES	PERCENT OF TOTAL
Quinault Indian Nation	44,260	28%
Bureau of Indian Affairs (Trust)	92,790	59%
Fee Allotments	20,089	13%
Other	124	0%
TOTAL	**157,263**	**100%**

QIN controls all activity with regard to forest operations on the 44,260 acres of operable land. The Bureau of Indian Affairs (BIA), as trustee for QIN, controls forest harvest operations on 92,790 acres and the QIN is responsible for all other activities under self-governance. The QIN also owns substantial interest in BIA trust allotments. In total, QIN and the BIA manage 87% of the total operable acreage within the reservation boundaries. The 157,263 operable acres represent 76% of the total 207,270 total mapped acres.

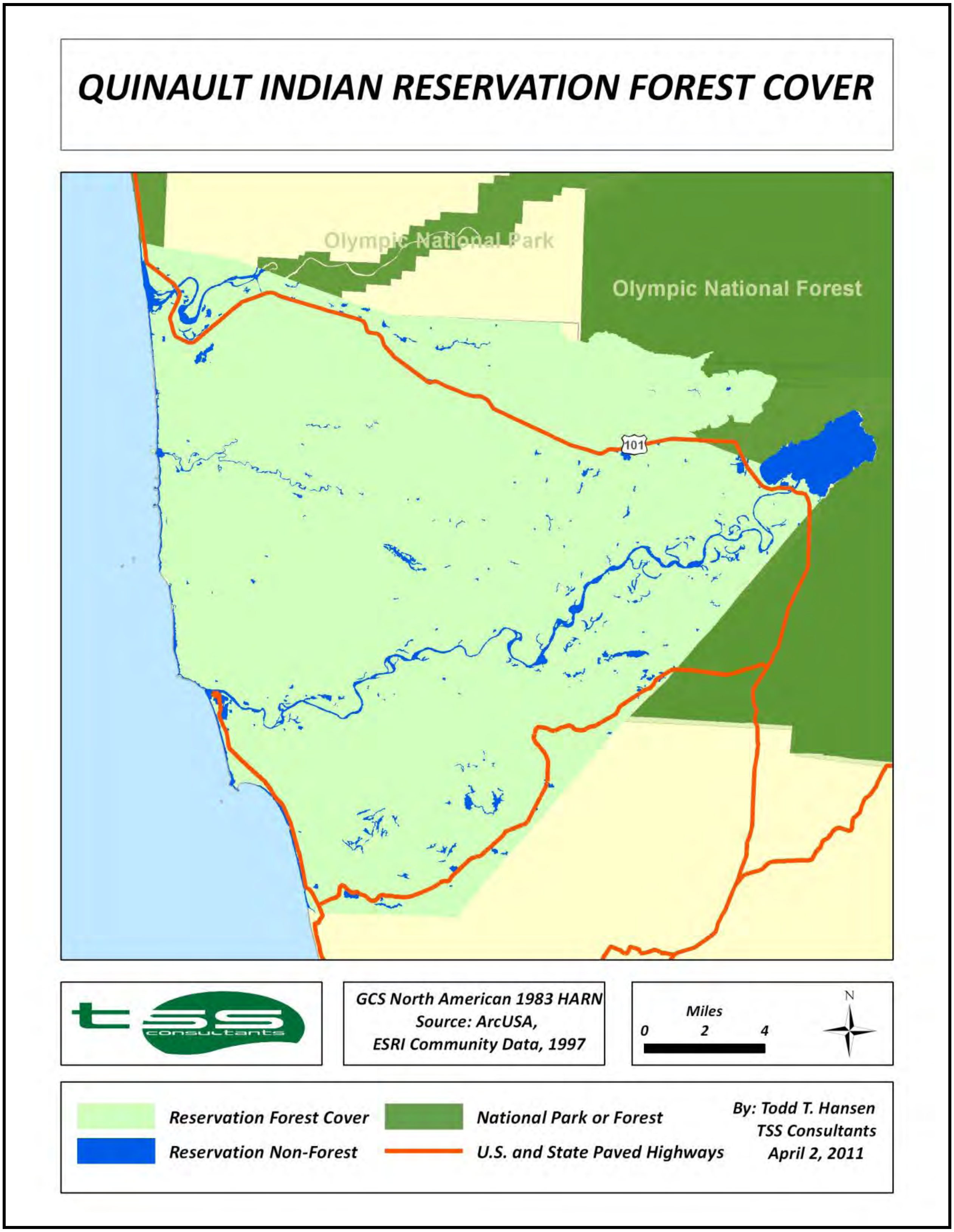
[2]The total acres are an estimate due to prospective inaccuracies associated with shorelines as property boundaries and interpretation of the extreme low tide datum.

The current ownership pattern for QIN consists of areas with concentrations of ownership (primarily in the northwest region of the reservation); however, the typical pattern is not one of contiguous blocks or parcels. QIN ownership consists of many scattered parcels dispersed throughout the reservation. The lands held in trust by the BIA are significantly more contiguous.

Woody biomass material available on a sustained basis, over time, and for a given area is directly dependent upon vegetation cover type. To appropriately confirm woody biomass material availability, it is necessary to evaluate vegetation cover types within the TSA. The primary vegetative data source used in mapping and analysis was derived from the existing QIN timber inventory and Geographic Information System (GIS) data.[3] Figure 3 highlights forested vegetation cover within the TSA.

[3]GIS data sets provided by Larry Wiechelman, QIN Inventory Forester and Anthony Hartrich, QIN GIS Program Manager.

Figure 3. Forest Cover Types Within the Quinault Indian Reservation



As Figure 3 clearly demonstrates, forest cover dominates the Quinault Indian.[4] The non-forested areas are delineated in the color blue because non-forest areas are primarily water courses (rivers and streams), lakes, non-forested wetlands/prairies, but also include urban areas. Table 5 shows the acres and percent of total for forest and non-forest cover within the TSA.

Table 5. Forest Cover Types and Acres Within the TSA

COVER CATEGORIES	ACRES	PERCENT OF TOTAL
Forest Cover	196,675	95%
Non-Forest	10,595	5%
TOTALS	**207,270**	**100%**

Table 5 demonstrates the substantive forest resource within the Quinault Indian Reservation. Approximately 95% of the entire reservation consists of forest cover. Of the total 196,675 acres of forest cover on the reservation, an estimated 157,263 acres are considered operable (Table 4).

Table 6 shows the breakdown of acres and percent of total for the various forest cover species.[5]

Table 6. Acres by Forest Cover Primary Species Within the TSA

PRIMARY FOREST SPECIES	ACRES	PERCENT OF TOTAL
Western hemlock	75,147	36%
Western red cedar	38,687	19%
Mixed Conifer	35,020	17%
Douglas-fir	24,160	12%
Hardwoods	17,388	8%
Non-Forest	10,595	5%
Lodgepole pine	6,273	3%
TOTALS	**207,270**	**100%**

The dominant forest cover type is western hemlock, comprising 36% of the TSA. Conifer forests comprise 87% of the total mapped acreage within the TSA and hardwood forests comprise 8%, primarily in association with water courses. The mixed conifer type is not characterized by a single dominant species but rather an even combination of at least two conifer

[4]Based upon analysis of GIS data sets provided by Larry Wiechelman, QIN Inventory Forester and Anthony Hartrich, QIN GIS Program Manager.
[5]Ibid.

species. Table 7 shows the number of acres by primary forest species for operable area within each ownership class.

Table 7. Acres by Primary Forest Cover Species for Operable Area by Ownership Class

PRIMARY FOREST SPECIES	BIA ACRES	QIN ACRES	FEE ACRES	OTHER ACRES	TOTAL OPERABLE ACRES
Western hemlock	35,459	15,519	9,622	84	60,684
Western red cedar	22,977	6,043	3,788	17	32,825
Mixed Conifer	17,241	9,772	2,109	0	29,122
Douglas-fir	8,421	9,463	3,107	1	20,992
Hardwoods	5,478	1,862	985	21	8,346
Lodgepole pine	3,213	1,602	478	0	5,293
TOTAL	**92,789**	**44,261**	**20,089**	**123**	**157,263**

The forested areas within the TSA are characterized by rolling to flat terrain with minor breaks (ridges and drainages). These conditions are conducive to cost effective timber harvesting and other forest operations, utilizing primarily ground-based yarding equipment as opposed to employing cable yarding systems. Table 8 shows the number of acres and percent of total suitable acres for ground-based and cable-based yarding within operable areas.[6]

Table 8. Acres by Harvest System for Operable Area Within the TSA

HARVEST SYSTEM	OPERABLE ACRES	PERCENT OF TOTAL
Ground-based yarding	142,633	91%
Cable yarding	14,630	9%
TOTALS	**157,263**	**100%**

As Table 8 shows, 91% of the operable area within the TSA is suitable for ground-based yarding. Typically, forest operations employing ground-based yarding have greater potential for cost effective biomass recovery. Ground-based yarding units will have most material yarded to the roadsides, including the tops if entire trees are yarded, and processing of trees into logs will occur on each side of the road. The majority of recoverable biomass material will be located within 100 feet on either side of the road. Cable yarded units will typically have small landings (though not always) with whole tree yarding, allowing processing of trees into logs on the landing. Typically the slash is pushed over the landing edge to provide room for landing yarded trees, processing, and loading logs onto log trucks. The small volume of material on landings

[6] Ibid.

coupled with slash material that may slide back down into the unit from the slash pile, confined operating conditions (on landings and on roads) and steep slopes typically results in increased recovery biomass costs when compared to biomass available from ground-based yarding units.

Biomass Availability

Timber harvest residuals can provide significant volumes of woody biomass material. Typically available as limbs, tops and unmerchantable logs, these residuals are byproducts of commercial timber harvesting operations. As such, these residuals can be a relatively economic raw material fuel supply. Once collected and processed using portable grinders, this material is an excellent biomass fuel source.

Woody biomass fuel review studies traditionally rely on data regarding historic timber harvest levels. This information can provide insight in determining historic trends and benchmarks to show actual forest harvest activities over time, activities that generate volumes of byproducts (as noted above) potentially available as biomass fuel.

The following discussion evaluates timber harvesting from 2006 through 2010 for both QIN and BIA-managed lands.

Quinault Indian Nation Ownership

As shown in Table 9, the QIN own and manage approximately 44,260 operable acres (28%) within the reservation boundaries. As mentioned earlier, the ownership is comprised primarily of scattered parcels rather than a block of contiguous parcels. Table 9 also shows acres by forest cover species within the QIN ownership.

Table 9. QIN Forest Cover Primary Species and Operable Acres

QIN PRIMARY FOREST SPECIES	OPEARABLE ACRES	PERCENT OF TOTAL
Western hemlock	15,518	35%
Western red cedar	6,043	14%
Mixed Conifer	9,772	22%
Douglas-fir	9,463	21%
Hardwoods	1,862	4%
Lodgepole pine	1,602	4%
TOTALS	**44,260**	**100%**

It is important to note that 91% of the QIN ownership consists of forestland and approximately 68% consists of operable forestland. The scattered nature of the ownership combined with the existing road system present challenges relative to woody biomass fuel recovery from timber harvest operations. Small parcels may provide limited quantities of recoverable biomass from harvest operations, which can result in increased recovery costs. Scattered parcels can present problems for effective biomass recovery as well, increasing mobilization cost of equipment employed in biomass recovery, and occasionally road systems designed solely for single parcel access and sawlog recovery can present logistical challenges for biomass recovery (poor chip truck access).

Table 10 shows the timber harvest volumes from QIN ownership within the reservation from 2006 through 2010. The harvest volumes shown here represent scaled sawlog and weighed pulp log volume, which is presented as thousand board feet (MBF).[7]

Table 10. QIN Timber Harvest Volume 2006-2010 (Expressed in MBF)

2006	2007	2008	2009	2010	AVERAGE ANNUAL HARVEST
8,658	3,349	9,481	10,170	16,630	**9,658**

QIN has harvested an average of 9.7 MMBF[8] per year over the past five years, ranging from a low of 3.3 MMBF in 2007 to a high of 16.6 MMBF in 2010. For timber harvest units operating over multiple years, the volume from those units was distributed evenly over those years for the data in Table 8.

Bureau of Indian Affairs Trust Lands

The Bureau of Indian Affairs (BIA), as trustee for QIN, control and manage forest operations on 116,440 mapped acres or 56% of the total area within the reservation. This ownership is comprised of more contiguous parcels than the QIN ownership. Table 11 shows acres by forest cover primary species within the BIA trust lands.

[7] MBF is thousand board feet measure. One board foot is a solid wood board measured 12 inches square by 1 inch thick.
[8] MMBF is million board feet measure.

Table 11. BIA Trust Lands Forest Cover
Primary Species and Operable Acres

BIA PRIMARY FOREST SPECIES	OPERABLE ACRES	PERCENT OF TOTAL
Western hemlock	35,459	38%
Western red cedar	22,978	25%
Mixed Conifer	17,241	19%
Douglas-fir	8,421	9%
Hardwoods	5,478	6%
Lodgepole pine	3,213	3%
TOTALS	**92,790**	**100%**

BIA trust lands consist of 97% forest cover, primarily western hemlock and western red cedar at nearly 60% of the total, and approximately 80% of the trust lands are considered operable. The ownership pattern is more favorable for biomass recovery than the QIN ownership; however, BIA trust lands still have challenges from the existing road systems and individual unit access for effective biomass recovery.

Table 12 shows the timber harvest volumes from BIA trust lands within the reservation during the period 2006 through 2010.

Table 12. BIA Trust Lands Timber Harvest Volume 2006-2010 (Expressed in MBF)

2006	2007	2008	2009	2010	AVERAGE ANNUAL HARVEST
9,499	14,664	15,282	8,979	36,168	**16,918**

The BIA timber harvest volumes show an average of 16.9 MMBF per year over the past five years, ranging from a low of 9 MMBF in 2009 to a high of 36.2 MMBF in 2010. The BIA timber sale data presented above was generated from timber cruise volume estimates, as opposed to scaled volume, which is the actual volume recovered as sawlog and pulp log material from the harvest unit. The QIN timber harvest volume data reflects scaled or recovered volume.

QIN Ownership and BIA Trust Lands

The QIN and BIA trust lands together comprise 137,050 operable acres or 87% of the total operable area within the reservation. Table 13 shows the operable acres by primary forest cover species.

Table 13. QIN Ownership and BIA Trust Lands
Forest Cover Primary Species and Operable Acres

PRIMARY FOREST SPECIES	BIA OPERABLE ACRES	QIN OPERABLE ACRES	TOTAL OPERABLE ACRES	PERCENT OF TOTAL
Western hemlock	35,459	15,518	50,978	37%
Western red cedar	22,978	6,043	29,020	21%
Mixed Conifer	17,241	9,772	27,013	20%
Douglas-fir	8,421	9,463	17,884	13%
Hardwoods	5,478	1,862	7,340	5%
Lodgepole pine	3,213	1,602	4,815	4%
TOTAL	**92,790**	**44,260**	**137,050**	**100%**

As noted earlier, 95% of the total acreage within the Reservation owned by QIN or managed in trust by the BIA consists of forest cover. Western hemlock comprises 37% of the total. Approximately 75% of the QIN owned and BIA managed lands are considered operable.

Table 14 shows the timber harvest volumes from both QIN ownership and BIA trust lands within the reservation for 2006 through 2010.

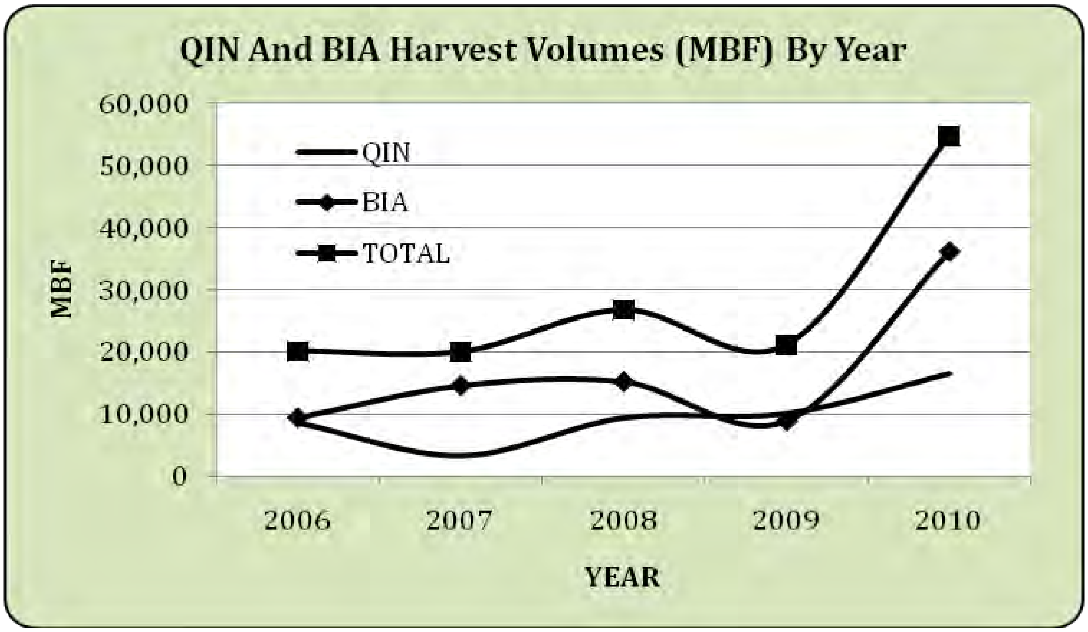
Table 14. QIN Ownership and BIA Trust Lands
Timber Harvest Volume 2006-2010 (Expressed in MBF)

MANAGER	2006	2007	2008	2009	2010	AVERAGE ANNUAL HARVEST
QIN	8,658	3,349	9,481	10,170	16,630	9,658
BIA	9,499	14,664	15,282	8,979	36,168	16,918
TOTALS	**20,163**	**20,020**	**26,771**	**21,158**	**54,808**	**26,576**

The data in Table 14 indicate fairly consistent timber harvest flow from 2006 through 2009, with a significant increase in 2010 (over double the five-year average). The five-year average is 26.6 MMBF.

The graph in Figure 4 shows timber harvest volumes from 2006 through 2010 from both QIN ownership and BIA trust lands.

Figure 4. QIN and BIA Timber Harvest Volume 2006-2010



The substantive increase in timber harvest and sale volume for 2010 is a byproduct of robust sawlog prices driven primarily by the log export market. Robust sawlog prices have created an opportunity for forestland managers with cost effective access to export markets or brokers to regain revenue foregone during the previous three years (as the housing and lumber markets experienced significant decline). Both QIN and the BIA took advantage of the increase in prices by expanding their timber harvest and sale program. In the case of the BIA, the anticipated loss of experienced personnel was also a contributing factor to preparing and selling as much timber volume as possible in 2010, knowing prospective shortfalls in future sale volume may be unavoidable due to manpower limitations.

The volume planned for sale or harvest from both QIN ownership and BIA trust lands for the past five years was approximately 33 MMBF per year. QIN staff estimated annual harvest volume to be sustainable at 10 MMBF per year, and the BIA staff estimated sale volume to be sustainable at 23 MMBF per year. The QIN 2006 through 2010 harvest volume average of 9.7 MMBF approximates the planned harvest volume (10 MMBF), achieving nearly 97% of planned harvest volume. The BIA five-year average sale volume of 16.9 MMBF is about 74% of planned harvest volume (23 MMBF).
The timber harvest planning process for the next ten-year period indicates anticipated annual harvest volumes of 15 MMBF for QIN and 31 MMBF for the BIA. Application of actual harvest volume versus planned volume from the previous five-year period (2006 through 2010) would yield harvest volumes of 14.6 MMBF for QIN and 22.9 MMBF for the BIA over the next ten years.

QIN and BIA Forest Operations Biomass Volumes

This analysis has focused upon recovery of suitable biomass material (for thermal energy production) primarily from timber harvest operations. Though biomass material may be generated through other forest operations, such as pre-commercial thinning, this biomass is typically not economically recoverable. Timber harvest operations generally provide large volumes of recoverable material in the form of limbs, tops and unmerchantable material. In ground-based yarded units, this material is usually located within 100 feet on either side of roads. The intent of pre-commercial thinning operations is to reduce the number of trees on each acre to mitigate inter-tree competition and increase growth on those trees selected to remain. Not all trees are removed, as in a typical regeneration cut harvest unit. Also, the trees are typically cut by hand, with the intent to leave on-site to decompose or are piled for burning. The low volume per acre of available material due to small tree size coupled with the difficulties of removing the material mechanically without damaging the remaining trees renders biomass recovery from pre-commercial thinning operations too expensive for use as biomass fuel on the reservation.

For both QIN and the BIA-managed lands, the byproduct from timber harvest operations represents the most viable opportunity to operationally and economically recover woody biomass material suitable as fuel for a thermal energy facility.

Based upon estimates of timber harvest volumes for QIN and the BIA, and adjusted to reflect past performance, Table 15 shows the estimated biomass material generated annually for the next ten-year period. The gross recovery factor estimate for biomass fuel processed from timber harvest residuals is approximately 0.9[9] bone dry ton (BDT) of woody biomass (tops, limbs, unmerchantable material) that could be generated from each MBF of timber harvested.

Table 15. Ten-Year Annual Harvest and Gross Biomass Volume Forecast

LAND MANAGER	TEN-YEAR ANNUAL ESTIMATED HARVEST VOLUME (MBF)	TEN-YEAR ANNUAL ESTIMATED BIOMASS VOLUME (BDT)
QIN	14,550	13,100
BIA	22,940	20,650
TOTALS	**37,490**	**33,750**

TSS estimates that 13,100 BDT are potentially available from QIN forest operations annually and that 20,650 BDT are potentially available from BIA forest operations annually, predicated upon forecast timber harvest levels for each over the next ten-year period.

9 Recovery factors are based upon interviews with logging and wood waste processing contractors as well as with private and public land managers experienced with recovery of biomass material processing and delivery in western Washington.

Biomass Recovery

The distinction between harvest units appropriate for ground-based yarding and those requiring cable yarding is important because methods to recover woody biomass and processing costs differ for each. On both QIN and BIA harvest units suitable for ground-based yarding, the timber harvest contractors typically utilize excavators (also known as "shovels") to yard or swing whole trees from within the unit to the roadside. The manufacture of trees into logs occurs adjacent to the roads, and the majority of slash material suitable for woody biomass fuel lies within 100 feet on each side of these roads for the length of the road where log processing occurs.

On those units requiring cable yarding equipment, whole tree yarding also occurs at a central landing point where the cable yarder is situated, and processing occurs adjacent to this landing, depositing unmerchantable material (slash and small logs) on the slope below. Though this slash remains somewhat consolidated, it is typically not piled on the landings.

While the majority of both QIN and BIA-managed lands are suitable for ground-based yarding, each contains some areas requiring cable yarding. An operability analysis of QIN and BIA-managed lands was conducted to separate timbered ownership suitable for ground-based yarding as opposed to areas requiring cable yarding. Table 16 shows the allocation of operable acres by QIN and BIA-managed lands.

Table 16. QIN and BIA Operable Acres Suitable for Ground-Based Harvest and Cable Yarding Harvest

LAND MANAGER	ACRES		PERCENT	
	GROUND	CABLE	GROUND	CABLE
QIN	36,769	7,491	83%	17%
BIA	86,480	6,331	93%	7%
TOTALS	**123,249**	**13,822**	**90%**	**10%**

Table 16 indicates an estimated 90% of operable acres within QIN owned and BIA-managed lands are suitable for ground-based yarding.

There are a number of biomass recovery methods currently employed in western and northwestern Washington on ground-based yarding units. Some contractors consolidate and recover slash material for transport to a central processing site for conversion (grinding or chipping) to suitable boiler fuel. Transportation costs (especially diesel fuel) and biomass fuel market prices limit these contractors' operating areas. Other contractors process the slash material on the harvest site. This material is either loaded directly into trucks for delivery to market or moved to a central location (collection site) suitable for depositing additional processed biomass and accessible by larger chip vans. These contractors are able to transport more weight as processed material as opposed to hauling unprocessed slash, and typically have a larger sourcing area, as hauling costs are more cost effective. The similarity between these two approaches is employing shovels to consolidate slash material alongside the roads in harvest units suitable for ground-based yarding equipment (ahead of loading or processing and loading).

For units requiring cable yarding, harvest logistics, road system and topography within both QIN and BIA-managed lands present challenges for the cost effective removal of biomass material. On some harvest settings there is insufficient room to configure processing equipment (tub grinder or horizontal grinder) and a conventional 40 to 48 foot chip van. On some settings the topography and road alignment preclude any option for a truck turnaround for anything less than a log truck with bunked trailer. In some instances, the road systems have a turning radius which is too tight for conventional chip vans, or the curve is immediately followed by road grade (slope) in excess of that operable for an empty conventional chip van and tractor.

Successful contractors operating in such conditions utilize a combination of methods to effectively recover biomass. These include deployment of an additional shovel below the landing itself, swinging material up to the shovel positioned adjacent to the grinder; utilizing trucks with adjustable or radio-controlled rear axles; utilizing containers or off-road dump trucks to move unprocessed material to the grinder or collection site. An additional option is deployment of military 6 X 6 type truck or similar powered tractor to haul shorter 26' chip vans into the unit for loading of processed material. Two of these 26' trailers may be loaded and delivered to a location on a road system suitable for conventional tractors to haul the tandem trailers to a delivery point for unloading. These contractors indicate recovery volumes are similar to ground-based yarding units; however, the cost of recovery is higher due primarily to the additional collection and handling costs.

Another option requires the loading and delivery of unprocessed material (slash) to a central location (collection site) adjacent to a road system suitable for use of conventional chip vans (48 foot to 53 foot "possum belly"). Within this operation there are a couple of alternatives: employment of roll-off type containers or modified dump trucks. In either case, material dispersed throughout the harvest unit on small landings is loaded into either the container or dump truck, hauled to the collection site and unloaded. The material is subsequently processed, loaded into chip vans, and hauled to market. Utilizing the roll-off containers rather than the modified dump truck incurs additional cost for unloading at the collection site and in reduced payload (capacity). Each of these alternatives has been utilized by woody biomass grinding contractors working in conditions similar to those on the reservation.

An important consideration in development of operationally and economically recoverable biomass from forest operations within the reservation is the absence of a conventional hydraulic truck tipper for unloading chip vans. The thermal energy facility fuel inventory and storage area is likely to require delivery using self-unloading trailers (also known as "live floor" or "walking floor" vans). This requirement would preclude forest biomass recovery operations employing tandem 26' vans as described above.

These methods of developing biomass from timber harvest operations recover from 0.3 BDT per MBF to 0.7 BDT per MBF. The lower estimate represents slash recovered and transported from second growth harvest units. In the data provided by QIN[10] staff relative to slash recovery conducted by Barrier West, Inc. (fiber processing company owned by Grays Harbor Paper), one unit consisted of old growth material with substantial quantities of non-merchantable material. The recovery rate for biomass in BDT per MBF was five times greater than the average for the second growth units. Discussions with QIN[11] staff indicated that harvest units similar to this were a fairly rare occurrence. For these reasons, this unit was not included in the biomass recovery metrics developed from QIN data. The upper recovery estimate (0.7 BDT/MBF) is derived from the experience of landowners and biomass processors currently recovering biomass from similar ecosystems and operating conditions in western Washington.

An evaluation of the existing road systems for both QIN and BIA-managed lands conducted by QIN staff[12] applied to the past five years of timber harvest activity indicated that from 15% to 30% of biomass may not be economically recoverable due to road conditions and the need to utilize live floor trailers to deliver processed biomass. The higher range reflects significant harvest activity in the North Boundary area northwest of Highway 101, which consists of a substantial number of units within the past five years requiring cable yarding with road systems presenting logistical challenges. Biomass recovery operations have occurred only within a mile of the Moclips Highway, and biomass material was removed and transported as unprocessed slash to Grays Harbor Paper. This operation was restricted relative to distance from the facility and distance from a paved road without the landowner providing financial compensation to assist recovery costs.

Employing operational filters of 75% (derived from the determination above, that from 15% to 30% of prospective biomass may not be effectively recovered based upon previous operations) of overall harvest volumes suitable for biomass recovery coupled with a recovery rate of 0.5 BDT per MBF (between the .3 and .7 BDT per MBF noted above) yields an estimate of practically available biomass. These recovery factors are applied to the 10 year annual estimated biomass volume in BDT from Table 15 above, which were developed from estimated timber harvest volumes for the next 10 year period. Table 17 shows TSS' estimates of potentially and practically available biomass from both QIN and BIA managed lands.

Table 17. QIN and BIA Potentially and Practically Available Biomass Fuel Sourced from Timber Harvest Activities (Expressed in BDT per Year)

LAND MANAGER	POTENTIALLY AVAILABLE	PRACTICALLY AVAILABLE
QIN	13,100	5,460
BIA	20,650	8,600
TOTALS	**33,750**	**14,060**

[10]James Plampin, QIN Silviculturist.
[11]Ibid.
[12]Larry Wiechelman, QIN Inventory Forester and Anthony Hartrich, QIN GIS Program Manager.

Estimated Costs

TSS has assessed the full expense of collection, processing and transport of biomass fuel from QIN and BIA-managed lands to better understand the cost of biomass fuel delivered to a prospective biomass-fired thermal energy unit located at Taholah. The estimated costs were generated as a result of interviews with biomass fuel processing contractors and timber harvesting contractors operating in western and northwestern Washington. The most significant variables impacting cost of processing and delivering biomass material include:

- Haul distance to market;
- Timber harvest residual pile distribution;
- Biomass material volume per acre;
- Access/road condition;
- Cost of diesel;
- Cost of labor;
- Road improvement and maintenance costs;
- Time of year delivery;
- Competing uses for the biomass material (e.g., pulpwood).

There are two alternative recovery methods with regard to delivered cost. Each method employs both 40' and 48' live floor trailers for fuel delivery. The in-forest biomass collection and processing costs range from $22 to $33 per BDT excluding truck transport costs. Transport costs are estimated at $90 per operating hour, loaded or empty, for both 40' and 48' live floor trailer and tractor. These costs reflect the experience of biomass processing contractors in the western Washington region under similar operating conditions.

<u>Alternative Recovery Method 1</u>

Some biomass processing contractors will evaluate harvest units to determine economic suitability and the extent of unit coverage to minimize processing costs to meet current markets. This approach typically includes evaluating harvest units and determining how far into the unit to proceed with processing equipment to maintain cost effective recovery. Contractors employing this recovery method typically will not recover roadside biomass from all accessible areas within the harvest unit. Though this alternative results in lower processing costs, prospective material remains on site and must be burned or left to decompose. Also, this alternative restricts the number of harvest units for biomass recovery.

Utilizing this model (Alternative 1) for biomass recovery results in delivered costs ranging from $33 to $58 per BDT (depending on haul distance and chip van size). Discussions with biomass processing contractors and fiber procurement managers in the region indicate biomass fuel moisture content ranges from 35% to as much as 65%. TSS assumed 50% moisture content to reflect delivered fuel moisture for this cost analysis.

The range of costs stated above reflects transport distance and differences in van capacity. TSS estimates that 40% of practically available biomass from QIN-managed lands and 50% from

BIA-managed lands can be treated employing this method. The difference between QIN and BIA recovery reflects differences in the road systems and harvest configuration employed for harvest units over the past five years. Seventy-five percent of this volume is recoverable from both QIN and BIA-managed lands using a 40' trailer and 25% is recoverable with a 48' trailer. Table 18 shows a matrix of fuel volume recoverable by each trailer size.

Table 18. Recoverable Biomass Fuel Volume – Alternative 1 (Expressed in BDT per Year)

LAND MANAGER	PRACTICALLY AVAILABLE BDT/YEAR	ALTERNATIVE 1 ECONOMICALLY RECOVERABLE	BDT RECOVERABLE BY 40' TRAILER	BDT RECOVERABLE BY 48' TRAILER
QIN	5,460	2,184	1,638	546
BIA	8,600	4,300	3,225	1,075
TOTALS	**14,060**	**6,484**	**4,863**	**1,621**

Table 19 is a matrix of delivered prices by trailer size as well as distance. The delivered prices below represent haul times of one-third hour to two hours (in one-third hour increments). The volumes for each are predicated upon harvest unit location from QIN and BIA-managed lands over the past five years for Alternative 1 as discussed above.

Table 19. Biomass Volume by Trailer Size and Delivered Price – Alternative 1

VOLUME ALLOCATION BY DELIVERED PRICE									
			DELIVERED PRICE ($/BDT)						
LAND MANAGER	**TRAILER SIZE**	**VOLUME**	**$33.95**	**$38.85**	**$43.60**	**$48.35**	**$53.25**	**$58.00**	**TOTALS**
QIN	40'	1,638	200	119	164	48	745	362	1,638
BIA	40'	3,225	597	635	1,051	361	400	181	3,225
TOTALS		**4,863**	**797**	**754**	**1,215**	**409**	**1,145**	**543**	**4,863**
			DELIVERED PRICE ($/BDT)						
LAND MANAGER	**TRAILER SIZE**	**VOLUME**	**$32.67**	**$36.91**	**$41.29**	**$45.53**	**$49.77**	**$54.14**	**TOTALS**
QIN	48'	546	67	40	55	16	248	121	546
BIA	48'	1,075	199	212	350	120	133	60	1,075
TOTALS		**1,621**	**266**	**251**	**405**	**136**	**382**	**181**	**1,621**

The results from Table 19 indicate an overall blended fuel price of $44.92/BDT for 6,484 BDT per year of biomass fuel recovered, processed, and delivered to Taholah.

Alternative Recovery Method 2

Some biomass processing contractors prefer to grind or chip all available material from the entire length of the road system within the harvest unit, as opposed to only conducting operations a certain distance into the unit, or avoiding some units completely that do not meet their cost requirements for recovery. These operations typically employ similar equipment to the biomass recovery operations from Alternative 1, but incur higher processing costs to ensure each unit is cleared of recoverable biomass material and ready for replanting or additional treatment. Overall recoverable fuel volume from each harvest unit is typically higher as well.

Utilizing this model (Alternative 2) for biomass recovery results in delivered costs ranging from $44 to $69 per BDT. As mentioned above, moisture content of 50% was used in the cost analysis. The range of costs reflects transport distance and differences in van capacity. TSS estimates that 60% of practically available biomass from QIN-managed lands and 70% from BIA-managed lands can be treated employing this method. The difference between QIN and BIA recovery reflects differences in the road systems and harvest configuration employed for harvest units over the past five years. Seventy-five percent of this volume is recoverable from both QIN and BIA-managed lands using a 40’ trailer and 25% is recoverable with a 48’ trailer. Table 20 shows a matrix of fuel volume recoverable by each trailer size.

Table 20. Recoverable Biomass Fuel Volume – Alternative 2
(Expressed in BDT per Year)

LAND MANAGER	PRACTICALLY AVAILABLE	ALTERNATIVE 2 ECONOMICALLY RECOVERABLE	BDT RECOVERABLE BY 40' TRAILER	BDT RECOVERABLE BY 48' TRAILER
QIN	5,460	3,276	2,457	819
BIA	8,600	6,020	4,515	1,505
TOTALS	**14,060**	**9,296**	**6,972**	**2,324**

Table 21 is a matrix of delivered prices by trailer size as well as distance. The delivered prices below represent haul times of one-third hour to two hours (in one-third hour increments). The volumes for each are predicated upon harvest unit location from QIN and BIA over the past five years as discussed above.

Table 21. Biomass Volume by Trailer Size and Delivered Price – Alternative 2

VOLUME ALLOCATION BY DELIVERED PRICE									
			DELIVERED PRICE ($/BDT)						
LAND MANAGER	TRAILER SIZE	VOLUME	$44.95	$49.70	$54.60	$59.35	$64.10	$69.00	TOTALS
QIN	40'	2,457	300	178	246	72	1,117	543	2,457
BIA	40'	4,515	835	889	1,472	506	560	253	4,515
TOTALS		**6,972**	**1,136**	**1,067**	**1,718**	**578**	**1,677**	**796**	**6,972**
			DELIVERED PRICE ($/BDT)						
LAND MANAGER	TRAILER SIZE	VOLUME	$43.67	$47.91	$52.29	$56.53	$60.77	$65.14	TOTALS
QIN	48'	819	100	59	82	24	372	181	819
BIA	48'	1,505	278	296	491	169	187	84	1,505
TOTALS		**2,324**	**379**	**356**	**573**	**193**	**559**	**265**	**2,324**

The results from Table 21 indicate an overall blended fuel price of $55.97/BDT for 9,296 BDT per year of biomass fuel recovered, processed, and delivered to Taholah.

Forest Products Manufacturing Residuals

Forest products manufacturing residuals in the form of bark and sawdust, collectively known as hog fuel, have traditionally been a source of low cost, readily available biomass in the forested regions of the West Coast. Due to a variety of factors (e.g., depressed housing markets), a large number of commercial-scale forest products manufacturing facilities have closed in the past several decades. These closures have dramatically reduced the volume of hog fuel available in the western and northwest Washington regions.

The closest forest products manufacturing facility to Taholah currently in operation is the privately owned TMI Forest Products, Crane Creek Division at Amanda Park, Washington. Located on the reservation, approximately 36 miles from Taholah, the Crane Creek sawmill produces fencing boards for residential markets. Discussions with TMI staff[13] indicate that approximately 13,000 BDT of hog fuel was produced in 2010. In the past, all of the hog fuel produced was sold to Grays Harbor Paper at Hoquiam. There is currently a surplus of hog fuel in the market due to removal of bark for the log export market.

Urban Wood Waste

Wood waste in the form of construction/demolition wood, pallets, and tree trimmings represents material that could be recovered, processed and utilized as biomass fuel. Typically available in large quantities from urban metropolitan centers, this material is collectively known as urban

[13]Steve Jasmer, Log Buyer and Residuals Manager.

wood waste. Many municipalities are now recovering urban wood before it is deposited in the landfills (its traditional fate) in order to divert material to other uses, thus extending the service life of landfills.

Discussions with Grays Harbor County Public Works Department staff[14] indicated that currently there is no wood waste recovery effort underway in close proximity to Taholah. The Hogan's Corner Transfer Station (most tributary to Taholah) is open on a very restricted schedule due primarily to the low number of County residents in the area, and it is not equipped to separate wood waste. The Grays Harbor Central Transfer Station (located just east of Aberdeen on Highway 12) does segregate and recover wood waste as confirmed by operations staff.[15] Currently all of the processed urban wood is being marketed as hog fuel into the Hoquiam/Aberdeen area. The additional haul distance (80 miles round trip) to transport urban wood from the Central Transfer Station, past current hog fuel markets in the Hoquiam/Aberdeen area to Taholah is significant. For the purposes of this analysis, it is assumed that there is currently no urban wood that is economically available for a thermal energy project at Taholah. One option for QIN may be to accept separated suitable wood waste at or near the thermal energy facility for accumulation and subsequent processing into suitable biomass fuel.

KEY ENVIRONMENTAL ISSUES/OPPORTUNITIES

Initial findings from work completed in support of the QIN biomass feasibility study (Task 2 Project Description and Task 3 Biomass Feedstock Availability and Cost Analysis) indicate that there are likely to be a number of environmental issues and opportunities associated with a biomass fueled thermal energy facility sited at Taholah.

A biomass fueled facility at the TMI Forest Products – Crane Creek Division facility located at Amanda Park was considered as a potential off reservation alternative. Discussions with the TMI Forest Products staff[16] indicates that TMI has no interest at this time in adding a biomass utilization facility to the Crane Creek Division plant site.

Potential environmental issues and opportunities are addressed here across three subject areas:

- Tribal community
- Tribal forest resources
- Target location site

[14]Mark Cox, Assistant Manager for Solid Waste, Grays Harbor County.
[15]Discussions with Ed Moreland, Waste Connections.
[16]Steve Jasmer, Log Buyer, TMI Forest Products.

Tribal Community

Job Training and Employment

A thermal energy facility located at Taholah would utilize locally available forest biomass resources as a primary fuel source. As noted in the results of the biomass feedstock analysis, there are significant forest biomass recovery opportunities on the QIN Reservation. In order to utilize forest-sourced biomass (generated as a byproduct of timber harvest activities) it must be collected, processed and transported to the thermal energy facility. These three cost centers – collection, processing and transport – all require skilled labor and specialized equipment.

A thermal energy facility on the reservation will require approximately 400 bone dry tons (BDT) per year, depending on the scale of the facility. This volume of material would amount to from three to five truckloads per month. Discussions with the Forks High School maintenance staff[17] confirmed that deliveries scheduled on a just in time delivery basis work best to minimize fuel inventory handling and exposure to precipitation.

There may be an opportunity to create a Tribal enterprise dedicated to the recovery of forest biomass for value-added uses. Due to the significant volume of forest biomass potentially available from reservation forest management activities, there could be an opportunity to market processed biomass (excess to on-reservation needs) to off-reservation markets (e.g., Gore Group Cosmopolis pulp mill) or as feedstock for a QIN enterprise.

In order to establish a forest biomass recovery enterprise on the reservation, there will be some very defined steps to consider including:

- Capital expense for equipment
- Job training program
- Safety and illness prevention program
- Marketing of processed forest biomass
- Financial analysis to confirm viability of business model

Air Quality

The vast majority of biomass resources available for recovery have traditionally been piled and burned on site. Diversion of forest biomass away from the traditional pile and burn fate and into a controlled combustion system with air emissions mitigation technology will likely result is a net improvement to air quality in the region.

Previous studies have documented the net reduction of significant air emissions associated with open burning of forest biomass as opposed to diversion to a controlled combustion system. A recent demonstration project involving the processing and 60-mile transport of mixed conifer forest slash for utilization as fuel in a biomass cogeneration facility provided the following criteria air pollutant emissions reductions (Springsteen et al., 2011):

[17]Bill Henderson, Maintenance Supervisor, Quillayute Valley School District.

- Particulate matter – reduced by 98%
- Oxides of nitrogen – reduced by 54%
- Carbon monoxide – reduced by 97%
- Methane – reduced by 96%
- Non-methane organic compounds – reduced by 99%

Results of this demonstration project are summarized in a January, 2011 article in the Journal of Air and Waste Management Association (see Appendix D attached). It is anticipated that forest biomass recovered from the reservation and utilized as fuel for thermal energy production will result in net air quality improvement in the region.

Cultural Resources

It will be important that a thermal energy facility located at Taholah fit in with the built environment. Specifically, any buildings constructed to house the facility must fit in with the surrounding buildings and landscape. Figure 5 is a recent image of the Forks High School facility, which was designed to fit in with the surrounding architecture.

Figure 5. Forks High School Thermal Energy Facility

Tribal Forest Resources

Use of Forest Biomass that is Currently Piled and Burned

As noted in the biomass feedstock availability and cost analysis findings, there is a significant volume of forest biomass generated as a byproduct of timber harvesting activities on the reservation. Not all of this forest biomass is economically recoverable. Much of this material (small chunks, limbs, needles) is retained on site and contributes to soil nutrient cycling.

Opportunity to Treat Overstocked Stands

Results of biomass feedstock availability and cost analysis confirmed that some pre-commercial and commercial thinning activities are conducted in forest stands on the reservation. However, due to low biomass volume generated, cost of recovery and potential damage to residual forest stands, there are limited opportunities to recover biomass from forest thinning projects that are planned on the reservation.

Target Location Site

Thermal Energy Demand

Three proposed buildings were targeted for biomass thermal energy delivery include a new school, community center, and emergency services/justice center. In addition, two existing buildings, the QIN Administration Complex and the QIN Health Clinic were also considered for thermal energy delivery. All five are projected to have significant thermal energy demand. Using a hot water thermal delivery system (similar to the Forks High School installation), it is anticipated that 100% of the thermal energy demand can be serviced using a biomass-fired system.

Water Availability

Water utilized by the thermal energy facility will be recycled and re-used so net water usage is minimal. Water is readily available at Taholah.

Road Access and Truck Traffic

There will be limited truck traffic associated with delivery of biomass fuel to the thermal energy facility. It is anticipated that between three and five truckloads per month of biomass fuel will be delivered to the facility. Deliveries will be made during daylight hours and typically on a Monday through Friday schedule. If necessary, arrangements can be made for weekend delivery to minimize commercial traffic during the week. Deliveries will be made using self-unloading trailers that can offload the fuel within 15 minutes.

Noise

The facility will be housed in a separate, self-contained and enclosed building, which will serve as a noise barrier. It is anticipated there will be little noise associated with the operation and maintenance of this facility. Truck deliveries will generate some noise, typical for commercial truck traffic.

Air Emissions

The facility will be equipped with the latest air emissions control technology (likely a bag house similar to the Forks High School facility). See air quality discussion (above).

Tribal Enterprise Opportunities

The thermal energy unit is expected to consume an estimated 400 BDT per year of woody biomass feedstock. Forest operations within the QIN and BIA trust lands could potentially generate between 14,000 and 33,000 BDT per year. QIN and ColPac requested TSS to evaluate the prospective costs incurred in establishing a biomass processing and delivery enterprise as well as potential value-added biomass utilization alternatives.

Regional Market Review

The most recent change in the local and regional market is the May, 2011 termination of operations by Grays Harbor Paper, a local paper manufacturer located in Hoquiam. The most significant impact on the thermal energy project at QIN is the loss of a potential woody biomass feedstock customer. The only other facilities burning significant volumes of wood for combined heat and power within the region are Sierra Pacific Industries and Cosmo Specialty Fibers. The Sierra Pacific Industries sawmill located in Aberdeen uses primarily the byproduct from wood products manufacturing to fuel their biomass-fired boiler. Cosmo Specialty Fibers in Cosmopolis is also able to procure necessary feedstock from local wood products manufacturing and the byproduct of whole tree chipping from local suppliers. Currently both companies are receiving significant volumes of bark from log export facilities removing bark from logs destined for export to China.

Though the short-term outlook for marketing woody biomass from forest operations on the reservation is not favorable, there may be changes in the marketplace that could change the long-term outlook for biomass fuel. Though the previous owners of Grays Harbor Paper have relinquished interest in the asset, the asset is currently subject to evaluation and prospective acquisition by other parties.[18] A recent announcement published in the local newspaper indicated that a letter of intent to purchase the former Grays Harbor Paper facility has been executed.[19] Operation of this facility once again would provide a local market for woody biomass feedstock.

The log export market is experiencing contractions as supply is nearing capacity overseas and China's demand is declining. This may reduce the volume of bark available from log export operations. The decrease in demand may be short term, as China's adjustments to raise interest rates and impose tighter credit requirements[20] have slowed the construction sector beyond the desired results. Log export company representatives have indicated that China will be relaxing the pressure on interest rates and the log export market will return to previous volumes, but at somewhat reduced prices. Historically, both Sierra Pacific Industries and Cosmo Specialty Fibers have avoided woody biomass from forest operations due to the possibility of introducing lower quality feedstock into their boiler and increasing operations and maintenance time and expense.

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[18]Discussion with Tim Gibbs, Grays Harbor Economic Development Council Executive Director.
[19] "Buyers for Grays Harbor Mill Named", The Daily World, April 20, 2012.
[20] "*China Market Befuddles Log Exporters*", Capital Press, by Mateusz Perkowski, December 29, 2011.

China's demand for raw logs has resulted in increased timber harvest activity in the west, especially for those owners or managers in close proximity to export facilities. This has increased the volume of sawlog and pulp logs in the market, though the majority of the sawlogs are destined for the export market. The current whole tree chip prices in the region for the preferred species of Douglas-fir and western hemlock range from $130 to $155 per BDT delivered. Though prices have stabilized somewhat after steadily rising for the past two years, should raw log export demand shrink, supply and prices for whole tree chips can be expected to rise. The demand and pricing for log exports has fueled timber harvest activity regionally. Local and regional wood products manufacturing companies are not able to pay prices for sawlogs commensurate with export prices, impacting their production levels. If the export market declines, timber harvest activity from private lands can be expected to decline as well, increasing pressure on pulp log acquisition and increasing prices. Though there are no local outlets, as noted above, current regional prices for delivered woody biomass range from $25 to $55 per BDT.

Given the current demand for whole tree chips, both consumers and suppliers are assessing alternatives to increase supply and reduce costs. A company whose core business is chipping for the pulp and paper industry throughout Washington has considered installation and operation of a satellite chipping facility in the area of the Quinault Indian Reservation in the recent past. Their evaluation concluded that transport of pulp logs to a stationary chipping facility located in the Hoquiam-Aberdeen area was the most cost effective alternative.[21] The primary reasons behind the decision were insufficient volume and production costs with portable chipping equipment. Portable chipping equipment production costs are nearly double the production costs of stationary chip mills. These costs are the result of decreased production and increased downtime with portable chipping equipment as opposed to stationary chipping operations. In addition, the chip quality from the portable equipment would not meet some customer's fiber specifications.

Prospective QIN Biomass Processing Enterprise

The typical equipment employed in recovering and processing woody biomass material as a byproduct of traditional forest operations consists of one or two shovels or excavators, a grinder or chipper, a dozer or skidder, and truck tractors and chip vans. The skidder and/or dozer may be employed to modify roads, assist in providing access for the chip van, or pulling equipment. The shovel or excavator is typically equipped with a modified bucket to aggregate and/or load forest slash material. Use of a tub grinder, horizontal grinder or chipper is usually dependent upon end market specifications and limitations (e.g., targeted chip size). Material suitable for a conventional industrial biomass boiler may not be suitable for small-scale thermal energy units. Small-scale thermal energy technologies are typically very sensitive to fuel sizing and usually prefer 3" minus chipped material.[22]

The most cost effective business model for biomass recovery is to process (chip or grind) in the harvest unit and load directly into chip vans. It may be necessary on occasion to utilize off-highway equipment, such as modified dump trucks, to relocate processed material for more

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[21]Discussion with Pat Tagman, Willis Enterprises.
[22]Per discussions with equipment vendors and thermal energy facility operators.

suitable access by conventional chip vans. In such instances, a front-end wheel loader will be necessary to load the chip vans. An alternative is to move unprocessed material (slash), using small vans or modified dump trucks, to a central location for subsequent processing, loading and transport. Such location would be selected to accommodate equipment necessary for processing as well as larger capacity chip vans. However, the additional material handling and the inability to maximize load capacity when hauling unprocessed material can increase overall costs significantly.

There are many companies engaged in both biomass processing as well as delivery. However, the best business model for QIN may be to develop two enterprises: one focused upon biomass recovery and processing and another focusing on transport. Separating the enterprises allows each to focus on the primary business; biomass production is not interrupted by truck maintenance or delivery schedule issues, and product deliveries are not impacted by biomass processing machinery maintenance and downtime. The transport company may contract with other enterprises moving product as well, and the biomass processing enterprise may rely on other transport companies during periods when the transport company cannot accommodate timely deliveries.

An array of chip van configurations may be necessary to access forest operations throughout the majority of the reservation. As noted earlier, there will be no hydraulic truck tip at the thermal energy facility; therefore, material delivered to this destination will require live floor trailers. Though any QIN enterprise focused upon transport will not need every configuration, a 40’ to 45’ live floor may best serve material for the thermal energy facility, and larger vans (53’ live floor or possum belly) might be used for longer transport distances (e.g., Grays Harbor/Aberdeen).

Table 22 provides a range of estimated capital costs for new and used equipment necessary for a business enterprise focused on forest biomass recovery, processing and delivery.

Table 22. Estimated Range of Equipment Cost

EQUIPMENT	NEW EQUIPMENT		USED EQUIPMENT	
	LOW RANGE	HIGH RANGE	LOW RANGE	HIGH RANGE
Tub Grinder	$300,000	$760,000	$100,000	$400,000
Horizontal Grinder	$500,000	$860,000	$100,000	$350,000
Horizontal Chipper	$165,000	$450,000	$75,000	$225,000
Shovel/Excavator	$160,000	$180,000	$112,000	$140,000
D5/D6 Cat	$170,000	$200,000	$70,000	$120,000
Skidder	$245,000	$275,000	$25,000	$60,000
Off Highway Dump Truck	$250,000	$350,000	$50,000	$100,000
Front End Wheel Loader	$265,000	$295,000	$40,000	$80,000
Chip Van 40' to 45' Live Floor	$73,000	$75,000	$25,000	$45,000
Chip Van	$60,000	$110,000	$15,000	$45,000
Chip Van Truck Tractor	$120,000	$140,000	$45,000	$70,000

If QIN elects to purchase equipment necessary to develop feedstock of specifications suitable only for the proposed thermal energy facility, TSS recommends a used, small-scale horizontal chipper and used shovel or excavator. The total cost for this equipment configuration, in good operating condition, ranges from $200,000 to $375,000. A truck and chip trailer with a live floor of between 40' to 48' in length, in good operating condition, would cost between $60,000 and $100,000.

Chipping is recommended as opposed to grinding, as the consistency of feedstock sizing from slicing woody biomass (i.e., the need for a chipper) is very important to both the conveyance system and boiler. Woody biomass processed through a tub or horizontal grinder is hammered (as opposed to sliced) into smaller pieces, and this process can produce a wide variety of lengths with varying thickness. This variation in feedstock sizing can be problematic for most thermal energy units and may create problems for feedstock conveyance.[23] In addition, these small boilers can be more sensitive to contaminants than industrial-scale boilers. In order to utilize woody biomass sourced from forest operations, the logging contractor as well as the biomass processing contractor must be very careful with slash handling to avoid introduction of dirt and/or rock into the slash pile. Since the thermal unit requires a fairly small volume (about 400 BDT per year), the most effective biomass recovery method would be to utilize slash material only from the top of the pile and leave material from near the bottom (where contamination is most likely to occur).

Though this equipment would generate feedstock of specification suitable for use in the thermal energy facility, this business model may not be cost effective for a commercial-scale biomass

[23]Interviews with thermal energy facilities confirm that chip sizing is very important.

recovery, processing and transport enterprise. Biomass production per unit of time employing the smaller chipper recommended above is well below production capabilities of larger (and more expensive) grinders and chippers. If QIN elected to purchase equipment to maximize use and production of prospective woody biomass from their forest operations, TSS would recommend purchasing a used, good condition tub or horizontal grinder and a shovel or excavator. The total cost for this equipment configuration, in good operating condition, would range from $215,000 to $550,000. Another alternative that may be suitable for production of feedstock for both the thermal energy facility and industrial CHP facilities would be the purchase of a horizontal grinder with adjustable screens and an optional attachment allowing production of chipped product as well. The transport enterprise would need several trucks and chip van trailers of various sizes. Purchase of three truck and live floor chip trailers would range from $180,000 to $350,000. This equipment configuration assumes minimal slash aggregation is necessary before processing, and that all areas considered for biomass recovery operations have access suitable for a 40' to 45' live floor chip van and truck. It is assumed that units with substantive access or operational limitations would not be considered.

There are a number of alternatives to improve biomass recovery volumes and production. If QIN elected to forego slash handling by the logging contractor and have the material aggregated by the biomass processing contractor (either QIN enterprise or outside contractor) to better control contaminant introduction into the feedstock, an additional shovel or excavator to assist in piling slash prior to chipping or grinding may be necessary. Should QIN decide to purchase equipment to access more of their forest operations to recover biomass, perhaps modified off-highway dump trucks and front-end wheel loaders may be necessary, as mentioned above. The trade-off for increased access, production and therefore biomass volume, is the cost of additional equipment.

Biomass recovery operations may be restricted during certain periods of the year (November through May) when roads and soils may be saturated. In order to ensure the QIN biomass processing contractor's weather-related downtime is limited, units suitable for processing during these conditions should be identified and retained for operating during such periods. In addition, it may be necessary to seek opportunities for operations on other adjacent landowners to ensure that downtime from lack of suitable operating units is limited.

The biomass recovery enterprise may employ from three to six people as equipment operators depending upon the business model and equipment purchased for the enterprise, and from one to two office personnel. The office staff would be necessary to handle accounting, payroll, load tracking, and other administrative duties. The transport enterprise may employ from two to five qualified drivers and from one to two office personnel. The number of qualified drivers would be predicated upon the number of truck and trailer combinations purchased. The office staff would handle accounting, payroll, dispatch, and other administrative duties.

TSS developed a biomass volume and cost estimate model using timber harvest volumes or slash pile estimates for forest operations in Excel format. The model allows the user to select the equipment a biomass processing and delivery enterprise might employ, as described above. The model worksheet interface and User Manual are included in Appendix C.

Value-Added Utilization Alternatives

A number of value-added alternatives are potentially available for utilization of the balance (after serving the thermal energy facility) of the biomass generated as a byproduct of forest operations for QIN. These could include integrating biomass recovery operations into markets currently consuming biomass as feedstock for combined heat and power; densified firewood substitutes such as logs or bricks; small community-scale combined heat and power; or residential fuel pellets.

If QIN elected to develop a biomass recovery, processing and delivery enterprise to service the thermal energy feedstock needs, the natural progression of the business model would be to market product to companies using wood-fired boilers within the region. Unfortunately, as mentioned above, the largest local consumer, Grays Harbor Paper, terminated operations in May 2011. However, the recent announcement regarding a potential buyer for the facility could bode well for local biomass market opportunities. Other prospective consumers are currently experiencing surplus capacity of suitable feedstock material, or are able to source feedstock entirely from within their manufacturing operations.

Residential Fuel Pellets

QIN staff requested that TSS address the potential opportunity for production of residential fuel pellets as a value-added alternative. Unfortunately, a number of factors render this prospective enterprise as unfeasible. The feedstock quality generated from forest slash used to produce fuel pellets would not meet market specifications. The typical feedstock used in the production of fuel pellets is clean sawmill byproduct such as chips, shavings and sawdust. This feedstock meets contaminant, moisture content and ash requirements.

Without careful handling to reduce green material (needles, leaves) and contaminant (dirt), feedstock from forest operations is not considered suitable. To properly handle and process such material would increase costs to the extent that the finished product would exceed current market pricing. This feedstock could be used in production of commercial-grade pellets; however, there are currently no markets for such material in the U.S. The market for this product also experiences seasonal fluctuations tied to heating needs.

In addition, there is currently excess capacity of residential fuel pellets in the marketplace. An increase in infrastructure (new plant development) occurred just as the economy began to decline. New entries lowered prices to gain market access as competition for market share intensified. These factors continue to keep prices at reduced levels. There are a number of closed or idled pellet plants throughout the Pacific Northwest. With existing plants operating at curtailed production levels and existing unused infrastructure, gaining market access, even during robust economic conditions, would prove difficult. Lastly, the current cost of natural gas is quite low (currently around $3.50/decatherm) and homeowners are reluctant to convert to a higher priced fuel such as fuel pellets.

Densified Firewood Substitute

The feedstock from forest operations is a viable source for production of densified firewood substitutes. Again, however, proper handling and processing of biomass material would be required to minimize potential contaminants (dirt, mud, silica, etc.). The typical densified firewood substitute is either a pressed brick or extruded log (such as Pres-to-Logs®). These products compete with conventional firewood and as such are typically marketed to appeal to prospective consumers with a fireplace, but not a desire to burn firewood, or where access to firewood is difficult and/or expensive. Consumers using wood stoves have been an increasing market, even more so than consumers with conventional fireplaces.

Though current production managers of such operations indicate that woody biomass from forest operations is a viable feedstock, moisture content, contaminant, and needles, leaves and twigs (fines) can impact production and quality. This feedstock needs to be dried to under 15% moisture content to be suitable raw material. Contaminant (dirt, rock) and/or needles, leaves and twigs can increase ash content, and therefore product quality and potentially, marketability. In addition to typical production equipment, feedstock dryers and screens will be necessary.

The estimated capital cost of installed equipment necessary to produce densified fire logs based upon production at 10,000 tons per year using screened feedstock at 50% moisture content would range between $2 and $4.2 million. The range of cost estimates reflects purchase of used, new or leased equipment. A significant cost for this enterprise is equipment necessary to dry the feedstock to suitable moisture content. This equipment can vary in price from $.5 to $1.5 million. The higher range represents new equipment using the same feedstock to fuel the drying process. The feedstock volume requirements to fuel both the production and drying process are estimated to be about 14,000 BDT per year.

The estimated capital cost of installed equipment for densified fire bricks based upon production of 10,000 tons per year with screened feedstock at 50% moisture content would range between $2 and $3 million. These cost estimates represent acquisition of good condition used equipment currently available in the market as well as new equipment. The price of the equipment necessary to dry the feedstock is significant, estimated at $.5 to $1.5 million, as above with fire logs. The feedstock volume necessary to produce an estimated 10,000 tons of product per year would be between 13,000 to 15,000 BDT per year, including the volume needed to dry raw material.

These estimates do not include the infrastructure recommended to house the operation. A total footprint of five acres covered in asphalt, with a concrete surfaced building of 10,000 square feet, should provide sufficient space. Covering the feedstock is also recommended to prevent introduction of additional moisture or contaminants. As mentioned above, the production process requires a feedstock with moisture content below 15%. Production steps include feedstock processing (chipped product is best), screening (minimize amount of needles, leaves, twigs and fines), drying, grinding, conditioning, compressing (extruded through a die or pressing into a brick), cooling and packaging. An example of equipment and cost for such production is included in Appendix E.

The personnel necessary to staff and operate these facilities could include a plant manager, one to two persons per shift primarily to handle packaging and maintain raw material supply for processing. Access to a millwright is especially important, although a full-time position is not necessary. The facility would need to operate at least two, eight-hour shifts per weekday to achieve production of 10,000 tons per year.

The current market for both firewood and the densified firewood substitutes is in decline.[24] The gross market may actually be growing slightly; however, new manufacturers entering the market have created an increased supply currently outstripping demand. The "net" opportunity to enter this industry is diminished at present. Both product lines are considered relatively inefficient heating sources, especially in a fireplace. The use of firewood or densified fire logs requires more time and effort to extract heat than other alternatives, such as natural gas. As noted earlier, natural gas is currently very cost effective. The base market has been relegated to a niche, focused upon the occasional consumer of firewood or an alternative strictly as environment enhancement rather than traditional heating source. The marketable advantages of firewood substitutes to firewood are increased heating efficiency (higher BTU), reduced emissions, reduced ash production through combustion, ease of storage and cleaner to use (no bark, no bugs, etc.) than firewood.

The product line is carried in a diverse array of retail outlets, from big box stores (e.g., Home Depot) to ranch and farm supply outlets, and on-line product sales and distribution websites. This product line is currently suffering from the same market dynamics as the residential fuel pellet industry. There is currently excess capacity in the market with diminished sales and idled production. Many of the same companies producing residential fuel pellets in the western U.S. also installed supplemental equipment to produce densified fire logs.

Two brands dominate the market: Duraflame and Pine Mountain. These companies have integrated production far beyond basic fire logs, offering an array of products with diversity in burn time, flame characteristics, and so on. Retail pricing may range from as low as around $1 to as much as $10 for an individual log. Pricing is predicated upon size, burn rate, density, etc. Some outlets offer bulk purchases of 130 fire logs for $143 and fire brick purchase of 800 for $255. Estimated pricing FOB[25] the manufacturing site for packaged product is $200 per ton.

A significant economic and strategic consideration is gaining access to an already saturated market. In many instances, new entries into the market attempt to gain access by offering their product at prices well below current market. This may gain a new entry short-term access, but the model is unsustainable. Eventually selling product to customers willing to provide shelf space at product pricing below market will force the existing competition to reduce prices to maintain market share and impact the new entry bottom line to the extent that continued operation is untenable. Perhaps the most appropriate market approach would be to remain a local or regional supplier searching for new markets or placing small volumes into existing markets at appropriate pricing.

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[24] Discussion with Mike Knobel, General Manager, Western Oregon Wood Products, Inc.

[25] Freight On Board, point of receiving or shipment.

Small Community-Scale Combined Heat and Power

Small community-scale combined heat and power (CHP) technology vendors have been working to improve the technology, efficiencies and lower delivered energy costs for some time. Most units have been considered too expensive to acquire, install and operate in the current power market. This dynamic is still true in the Pacific Northwest where consumers have ready access to inexpensive hydropower. In some rural areas, these technologies are well suited. For some enterprises, even though the power may cost more, the concept of controlling and owning the power supply is an appealing objective.

One example of a promising CHP technology vendor is Phoenix Energy, LLC, headquartered in San Francisco, California, who has developed a scalable CHP system. The company currently has a small unit operating in Merced, CA producing 500 kW. The technology employed is a thermo-chemical conversion process also known as a gasification system. The facility conveys woody biomass to a gasification unit for conversion to synthetic gas. The gas is subsequently cooled and conditioned (impurities removed), and then delivered as fuel to a modified internal combustion engine power generator for electricity distribution.

For this particular unit, the waste heat could be recovered and used for pre-drying feedstock prior to utilization; however, there would not be sufficient excess heat to replace the thermal energy needs for the buildings at Taholah. An additional byproduct of the entire process is biochar. This facility is currently marketing the biochar as soil amendment to a variety of purchasers in central California and receiving over $100 per ton.[26]

The unit is currently fueled by local agricultural byproducts and clean reclaimed construction material. A unit of this size (500 kW) would consume an estimated 3,000 to 5,000 BDT per year. This unit has been in operation since passing and completing its commercial testing in March 2011. TSS estimates of energy load (electricity needs) for the community of Taholah indicate that a unit of comparable size, 500 kW, would be sufficient.

The entire footprint for the facility is one acre. The feedstock inventory is stored in a used chip van with a belt drive self-unloading system. Phoenix Energy uses the belt drive to move feedstock to the end of the van where an auger is used to convey fuel to the gasification unit. Figure 6 shows the facility located in Merced, CA.

[26]Per discussions with Phoenix Energy Staff.

Figure 6. Phoenix Energy CHP Unit

The basic equipment set-up includes feedstock receiving system, feedstock storage, conveyance, gasification unit, syngas cooling and conditioning configuration, and Caterpillar generator set (modified internal combustion engine). The estimated cost of this equipment, installed and operational, is $2.25 million. An additional $.5 to $1 million would be necessary for feedstock drying equipment.

Feedstock Analysis Results

Three feedstock samples were sent to Hazen Research, Inc. of Golden, Colorado. Hazen 's laboratory conducts analytic characterization of woody biomass material processed for boiler fuel. Table 23 shows the results of the analyses.

Table 23. Feedstock Analysis Results

FUEL SAMPLE ANALYSES							
	AS RECEIVED				DRY		
SAMPLE TYPE	MOISTURE %	ASH %	SULPHUR %	HHV BTU/LB	ASH %	SULPHUR %	HHV BTU/LB
Chipped Forest Sourced Material	39.68	1.10	0.008	5273	1.83	0.013	8741
Ground Forest Sourced Material	51.92	0.77	0.106	4357	1.61	0.220	9061
Ground Forest Land Clearing	38.59	3.25	0.128	4958	5.29	0.208	8073

Both feedstock samples from forest-sourced material had higher heating value (HHV) than feedstock from land clearing conducted on forestland. While representatives of both Messersmith and Skanden indicated that their systems would experience problems with typical feedstock processed using grinders (tub or horizontal) due primarily to size variation and occasional larger pieces, they indicated their systems should not have issues using the chipped product.

SITE REVIEW AND SELECTION

TSS conducted an examination of potential sites on the QIN Reservation where a forest-sourced biomass utilization facility could be installed and operated. This biomass utilization facility would be a thermal-only unit, meaning that it will use wood waste to heat water to potentially supply hot water to heat selected QIN buildings.

A site review of potential locations for the biomass thermal facility was conducted for this task. The specific site attributes listed below were considered:

- Land Use Zoning
- Transportation, Routes, and Corridors
- Public Health and Safety
- Water Supply Resources
- Geology/Soils
- Cultural Resources
- Potential Co-location Opportunities

Initially two potential sites were considered: one site is located within the northeast Village of Taholah (Figure 7); the other site examined was adjacent to the TMI Forest Products, Crane Creek Facility (Figure 8), which is located on U.S. Highway 101 approximately four miles east of Lake Quinault. However, discussions with the TMI Forest Products staff indicated that TMI has no current interest in having a biomass utilization facility at their Crane Creek plant. Thus, this site will not be considered further in the selection process and only the Taholah site will be examined below.

Figure 7. Taholah Site

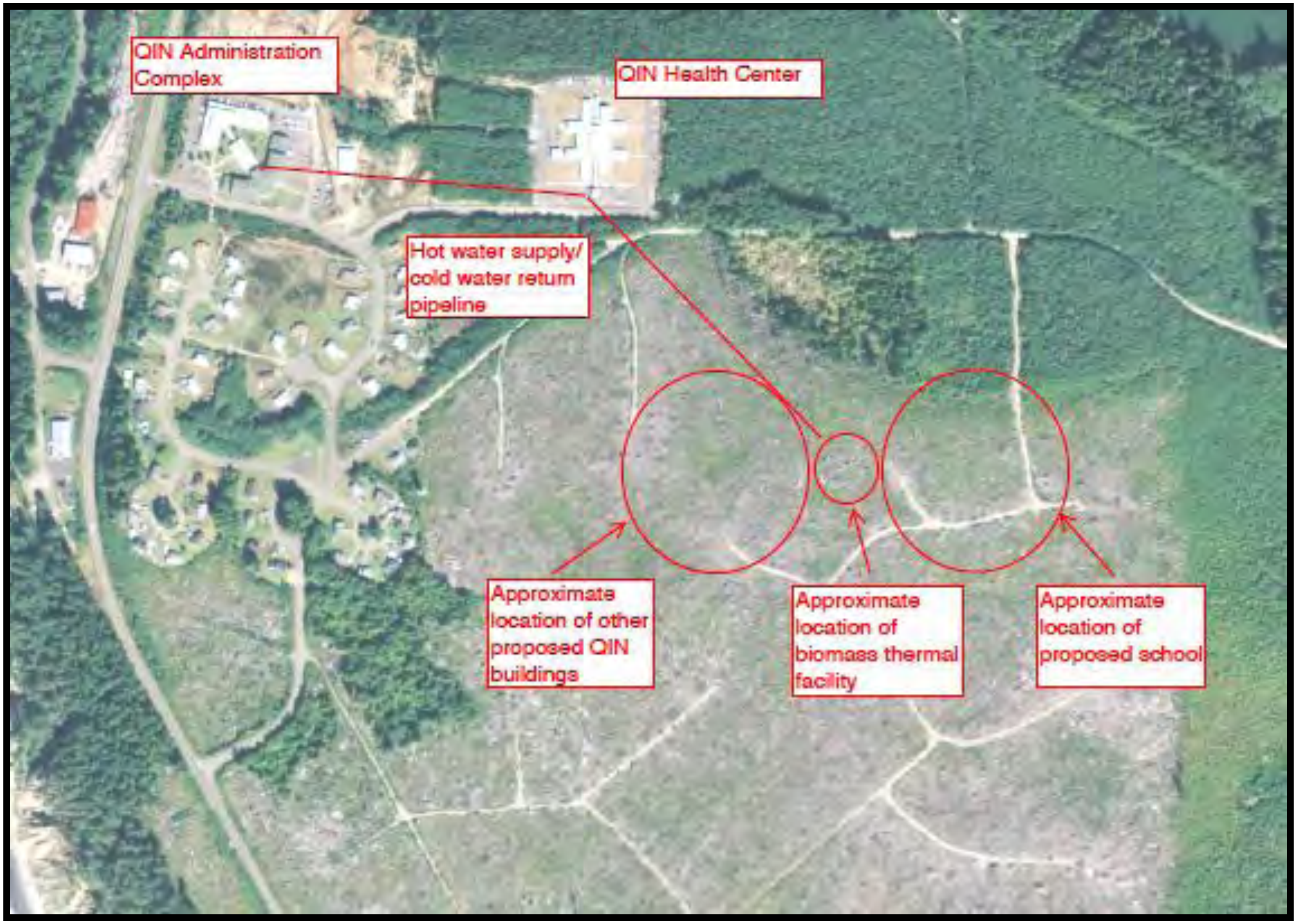
TSS Photo November 2010

Figure 8. Crane Creek Site

TSS Photo November 2010

The Taholah site holds promise for a biomass thermal facility as it has both proposed and existing buildings which could potentially use hot water generated by a biomass-fired system for space heating. The Taholah School, fire station, and emergency medical services, currently located near the coastline, are proposed for relocation to this area (see Figure 9), to be out of the lower elevation tsunami inundation zone. The biomass thermal facility will be located adjacent to these buildings, most likely the school, as that facility will be the first one built. During the site visit on November 8, 2010, and in discussions with the QIN and ColPac representatives, it was determined that two existing buildings in Taholah may be suitable for connection to the hot water heating system via buried insulated pipelines. These two buildings are the QIN Health Clinic on Kla-ook-wa Drive (see Figure 10) and the buildings on Aa-lis Drive that house the QIN Administration, Natural Resources, Executive Offices, and the Tribal Council Chamber (Figure 11).

Figure 9. Preliminary Siting Map for Quinault Indian Nation Biomass Thermal Heating System



Aerial photo courtesy of QIN

Figure 10. QIN Health Clinic Building

Larry Workman, QIN

Figure 11. QIN Administration, Natural Resources, Executive Offices

Larry Workman, QIN

Land Use Zoning

In consultation with the QIN Planning Department,[27] the proposed site was examined for project suitability under land ownership and the current zoning for the proposed site area. Project site suitability is also a function of ownership and operation of the biomass thermal facility. There are potential scenarios for the biomass thermal facility ownership: 1) the facility is owned and operated by the QIN or 2) the facility is owned and operated by a private third party. The zoning effect on facility ownership/operation will be discussed further below.

[27]Jonathan Ciesla, Land Use Planner, QIN Planning Department.

The proposed site area encompasses two different property ownerships and two different zoning areas. The west side of the project site circle in Figure 12 is on undivided trust land. The QIN owns at least 50% so they can do a lease with the trust land owners, and there would likely be annual lease payments to the individual owners. Real property in the east side of the project area circle is owned fully by the QIN and where the new school is to be located is leased to the Taholah School District. The biomass thermal facility, if located next to the school on the district leased property, would need to be approved by the school district.

Figure 12 displays the zoning in the project area. The potential site area for the biomass thermal facility overlays both Residential and Commercial zones[28]. The west side of the project area circle is Commercial, with the east side being Residential. If the biomass thermal facility is owned and operated by the QIN, it would classify as a public building, and public buildings are allowed in both Residential and Commercial zones. If the facility is owned and operated by a private third party, it would not be an allowed use in the Residential zone. It would have to be rezoned as a Commercial or Industrial zone.

Based on the above, regardless of facility ownership, it would be allowed in the Commercial Zone. Plus, it may be more appropriate from a safety perspective to put the biomass thermal facility next to the proposed civic buildings in the Commercial Zone. The QIN Planning representative agrees with this.

Piping (buried) of the hot water for the biomass thermal system to non-adjacent buildings (such as the QIN Adminstration Complex buildings and the Health Center - see Figures 10 and 11) will require an easement across the undivided trust land. An easement-like instrument should be used for pipeline routing across QIN solely-owned property.

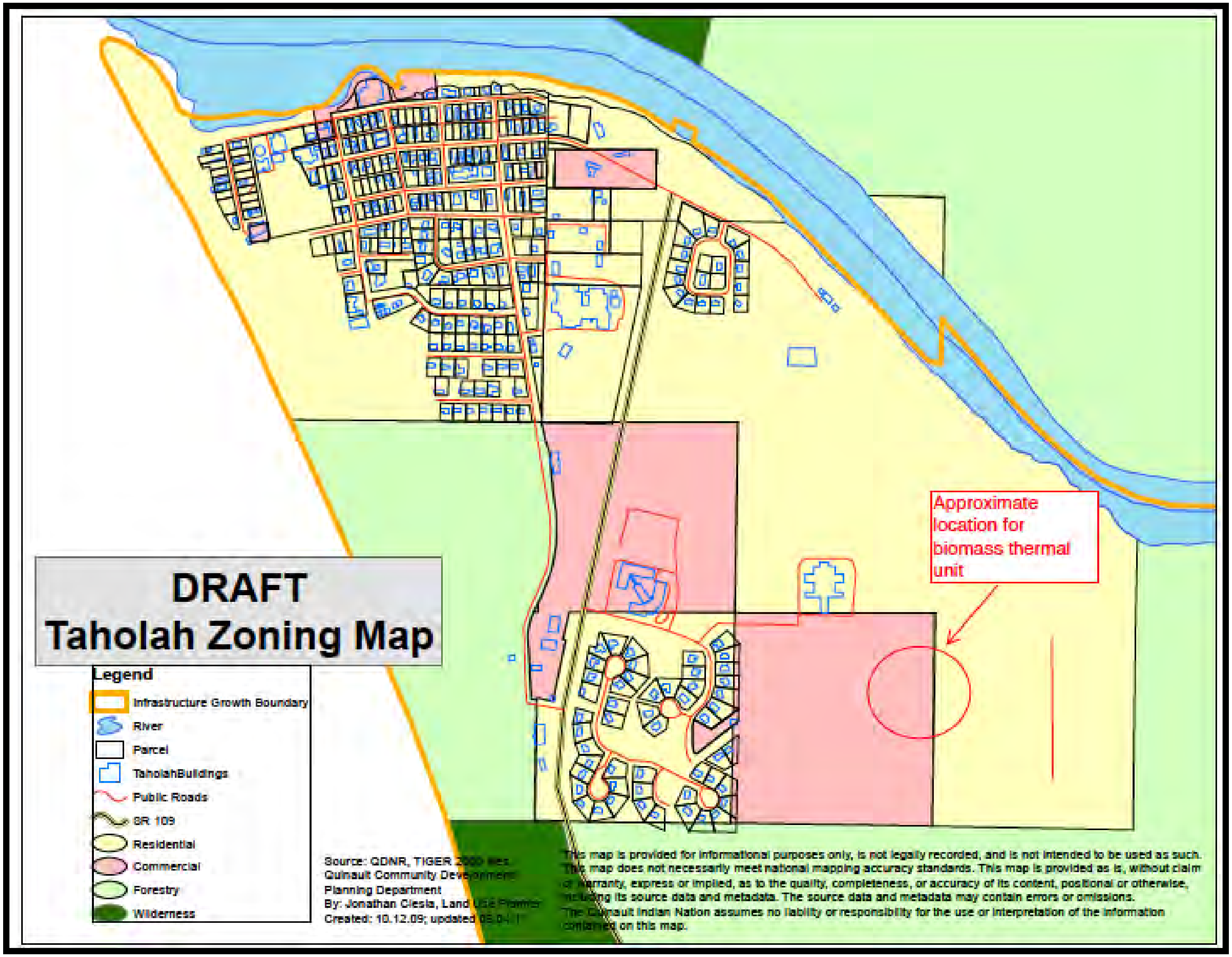
Transportation, Routes, and Corridors

The reservation includes three (3) major transportation corridors: State Route 109 (SR 109) serves the coastline from Moclips to Taholah, United States Highway 101 (US 101) runs from Amanda Park through the north end of the reservation past Queets, and Moclips-Olympic Highway (Indian Reservation Road Route 26 (IRR Route 26) connects the two.

From SR 109, the biomass utilization facility site would be accessed via Aa-lis Drive, and Kla-ook-wa Drive, which is being extended to service the proposed school (see Figures 12 and 13).

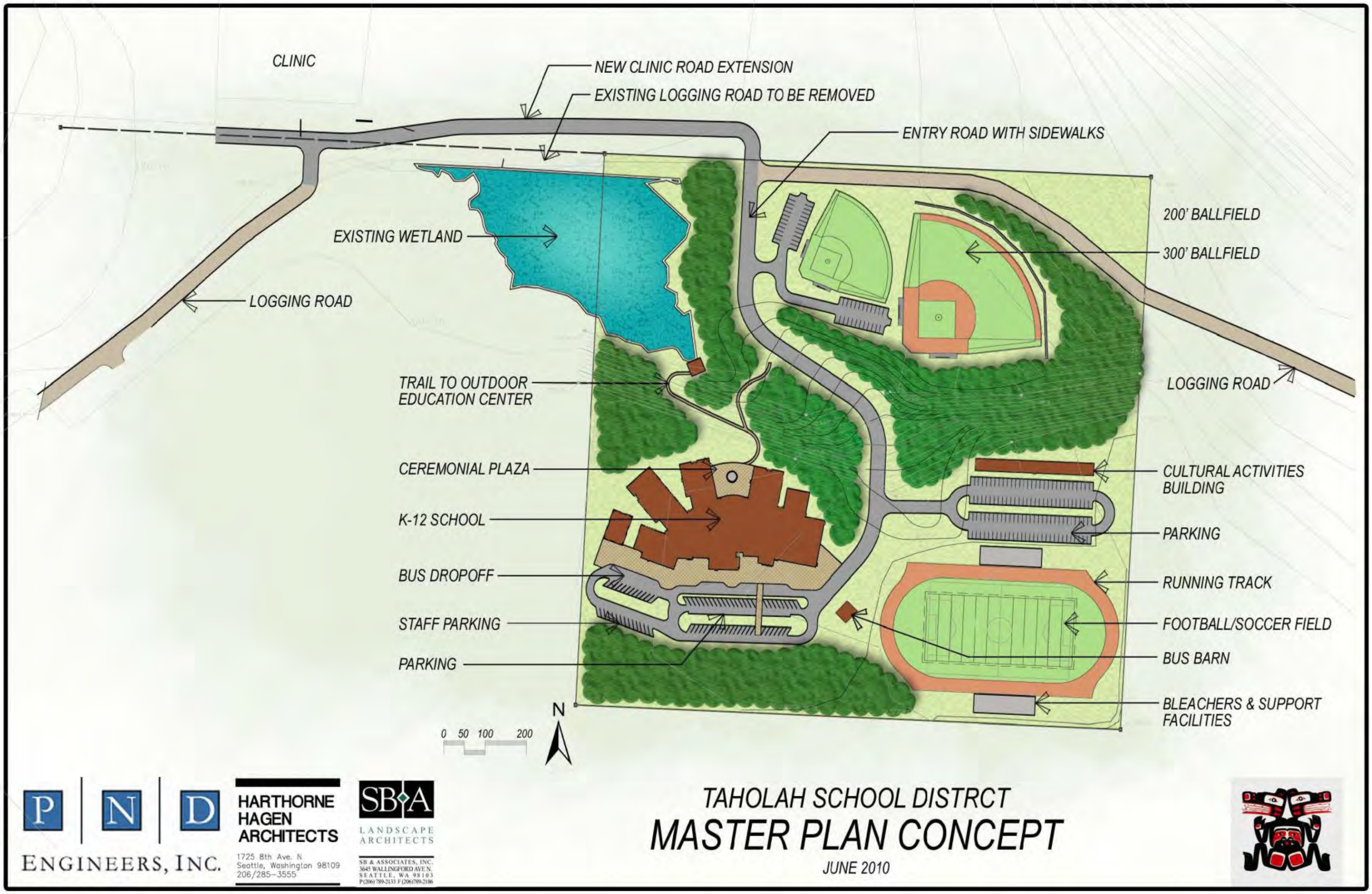
[28]Note: The zoning in Figure 14 has not been finalized.

Figure 12. Quinault Indian Nation Zoning



Map courtesy of QIN Planning Dept.

Figure 13. Proposed School



Based on the amount of biomass fuel needed annually (see Technology Selection and Financial Analysis section below), estimated at 398 bone dry tons (BDT), if 48 foot trailers are used which are capable of carrying 13.5 BDT per load, this calculates to 30 trucks per year, or less than an average of 1 per week. However, as discussed in the Key Environmental Issues/Opportunities section, deliveries would most likely be on an as needed basis, so deliveries would occur more frequently during the months when more space heating of the buildings was needed. This might increase deliveries to twice per week during those periods.

Public Health and Safety

The proposed biomass thermal site should pose minimal or no impacts to public health and safety. There will be a weekly large chip truck delivery, but this delivery time could be scheduled to avoid times when the school is in session, or it has been suggested by QIN representatives that perhaps deliveries could occur during school hours so as to avoid children on the access streets. In addition, given the layout of the proposed school, it may be best that the biomass thermal unit have separate access from Kla-ook-wa Drive, possibly just east of the existing wetlands indicated in Figure 13.

A biomass thermal system generating hot water for space heating would be a low pressure system, with the hot water delivery system underground for the most part. The building housing the biomass thermal system could have automatic sprinklers installed for fire protection. No chemicals, other than petroleum-based lubricants and hydraulic fluids as well as some water softening chemicals, would be necessary for operation of the system.

From an air quality and permitting perspective, the biomass thermal system could improve air quality in the area. As stated in the Key Environmental Issues/Opportunities section of this report, controlled combustion of biomass as opposed to uncontrolled, open pile burning can significantly reduce air pollutants. Of particular concern in the Taholah area is when local open burning of forest wood waste takes place. The QIN Air Quality specialist[29] indicated that the smoke from these events can exacerbate asthma conditions in several of the Taholah residents. If the forest waste could be used in the biomass thermal unit, the particulate matter (PM) emissions (the emissions most detrimental to asthma sufferers) could be reduced by over 99%.

Water Supply Resources

A biomass thermal unit, with water as the heat transfer mechanism in the various buildings, would consume very little water. Once the system was initially charged with water (with several thousand gallons, depending on how many buildings were to be supplied with low pressure hot water for heating), makeup water would be minimal.

A QIN utility representative[30] has confirmed that 1 to 2 gallons per minute of makeup water could easily be supplied to a closed loop hot water heating system. The system would most likely not require this amount of water.

[29] Lisa Riener, QIN.
[30] Jim Figg, QIN.

Geology/Soils

According to the federal Natural Resources Conservation Service soil survey, the soils are Calawah medial silt loam with 1 to 8 percent slope.

There are numerous earthquake fault zones near Taholah, both onshore and even more offshore. The Cascadia Subduction Zone, where the San Juan de Fuca and North American tectonic plates meet, also traverses the Taholah area and is a very significant seismically active region. Design and construction of the biomass thermal unit and any accompanying structures and equipment must consider the potential for significant seismic activity conditions.

Cultural Resources

The preservation of cultural resource by the QIN is of paramount importance. A QIN cultural resources representative[31] indicated that there are no known sensitive cultural resources at the proposed site.

Potential Co-location Opportunities

The proposed biomass thermal site is intended to take advantage of co-location opportunities by siting adjacent to the proposed new school and other proposed civic buildings as described. It may also be within economic distance[32] to the QIN Administration buildings and the QIN Health Clinic.

Findings

Based on the above findings, the proposed site, particularly if sited on the Commercial zoned property, can support a biomass thermal system.

TECHNOLOGY SELECTION AND FINANCIAL ANALYSIS

Utilizing the findings from Tasks 2 through 5, this section of the report reviews applicable biomass thermal technology and further evaluates two representative technologies[33] for use at the QIN site in Taholah. Financial analysis is also conducted for these technologies.

Technology Selection

The first phase of this section of the report is the presentation of two technologies (via their respective vendors) that optimize the use of forest-sourced woody biomass for generating cost-effective and environmentally acceptable thermal energy at the Taholah site. The biomass-fired heating technology believed to be best suited overall for the various Taholah installations, and

[31] Justine James, QIN.

[32] Economic distance means a distance from the biomass thermal unit supplying hot water to a building for heating that allows the cost of such heating to be economically feasible.

[33] These technologies are considered representative of the several small-scale biomass thermal technologies in the current marketplace.

especially the proposed new buildings, is a medium to high temperature hot water system wherein wood chips are direct combusted in a furnace/boiler and water is heated and piped to buildings where heat exchangers transfer the thermal energy in the hot water to heat space or to provide hot water for domestic use. Steam systems are not as efficient and tend to incur higher maintenance costs. However, like the Darby, Montana elementary school installation (and many other older existing schools) where a steam system was already in place (prior to installation of new biomass system), it sometimes makes economic sense to remain with the steam piping and heaters rather than incurring the expense of converting to hot water.

Based upon information supplied by QIN in regards to existing and proposed buildings at or near the Taholah site, TSS estimates that a 1.25-1.5 million Btu per hour (MMBtu/hr)[34] thermal energy unit should be sufficient (based on potential peak demand). This is based on Table 24. Table 25 indicates the amount of woody biomass that would be needed on an annual basis to supply the system.

[34]Million British thermal units is a traditional measure of heat energy. One Btu represents the energy required to heat one pound of water from 39 degrees F to 40 degrees F.

Table 24. Project Buildings and Projected Heat Loads

EXISTING BUILDINGS	SIZE (Sq Ft)	HEAT SYSTEM	USE	COST ($/Yr)	ELECTRICITY COST (¢/kWh)	ACTUAL USE (kWh/Yr)	ACTUAL USE (Btu/Yr)	% HEAT[35]	HEAT (Btu/Yr)
Administration Complex	59,603	Electric	50 hrs/wk	70,140	7	846,240	2,888,217,120	57.5	1,660,724,844
Health Center	28,485	Electric	50 hrs/wk	51,840	7	959,760	3,275,660,880	57.5	1,883,505,006
PROPOSED BUILDINGS					**HEAT (Btu/Sq Ft)[36]**				
School	25,000	Electric	50 hrs/wk-9 months/yr		27,863				696,577,707
Emergency Services[37]	14,000	Electric	7/24/365		83,589				1,170,250,549
Total Annual Heat-Btu									5,411,058,106
Total Annual Heat-MMBtu									**5,411**

[35]Assumes 70% of electrical use for 9 months is heat and 20% for 3 months for hot water, etc. ((70 x 9 + 20 x 3)/12)) = 57.5%.
[36]Administration Complex heat per year divided by Administration Complex area.
[37]Administration Complex use is 2080 hrs/yr (50 hrs x 52 wks) while Emergency Services would be heated around the clock, requiring about 3 times as much heat.

Table 25. QIN Biomass Thermal System Operating Parameters

PARAMETER	VALUE
Annual Heat Required - MMBtu	5,411
Peak Heat Required - MMBtu/hour	1.5
Estimated Boiler Efficiency	85%
HTW Transmission Losses	2%
System Efficiency	83%
Heat Required from Biomass - MMBtu/year	6,519
HHV of Biomass - Btu/lb.	8,200
Biomass Required – lbs./year	795,042
Biomass Required - BDT/year	398

Potential Heating Systems

As mentioned above, the technology type TSS believes is best suited for the Taholah site is direct combustion. Gasification technologies would add another level of complexity and costs (both capital and operating), which is not necessary for the Taholah site.

Systems like Messersmith Manufacturing, Inc., direct combustion systems are relatively easy to operate with auger systems automatically feeding the fuel into the furnace/boiler and monitoring the rate of fuel feed with temperature control systems, which maintain a set temperature in the spaces requiring heat. The Messersmith system requires only manual removal of ash, which is a daily task requiring about 15 to 20 minutes. The Messersmith combustion system is used at Forks, WA and Darby, MT to provide heat to schools. The capital cost of the system at Darby, for a 3 MMBtu/hr system, was about $537,000 installed which did not include the hot water distribution system, heat exchangers, emissions controls, or engineering design. The system uses wood chips sized at about 2 inches by 2 inches by ½ inch. The Forks, WA biomass thermal installation is a 2 MMBtu/hr system and is reported to cost $1.6 M to construct, including design and engineering.

The other potential candidate direct combustion system is Skanden Boilers, which TSS has previously evaluated, in a technical and financial study for supplying biomass-fired heat to the Sierra at Tahoe ski resort near Lake Tahoe, CA. The unit evaluated in that previous study supplied .85 MMBtu/hr of thermal heat and the installed capital cost was estimated at $255,000. This cost included about 1,000 feet of distribution piping and 20 heat distribution units.

However, this was not a complex system, buildings were located close together, and do not include any emissions control systems. (A single Skanden Boiler unit fell under the local air district's threshold for add-on controls.) The Skanden system is also fully automated, including automatic removal of ash. Skanden manufactures units in the 1 to 2 MMBtu/hour size. A promising option could be to use three Skanden units at Taholah, which might eliminate the requirement for an oil-fired backup boiler, which could be required for the proposed buildings. Nearly all biomass heating systems for schools have an oil-fired emergency backup boiler.

However, the electric systems in the existing buildings might be used for backup and electric systems also installed in the proposed buildings. The detailed engineering/design study would determine which approach would be most economical. The three Skanden boilers would be located at a single central location just like the single Messersmith unit. A hot water distribution line would go from the central location to the various buildings. The line would consist of a supply line and return line buried in the same trench. The lines would be insulated, and the insulation would keep the temperature drop in the delivered hot water to less than 1 degree Fahrenheit per 1,000 feet of distribution line. An alternative would be to use un-insulated lines, which would reduce the installed capital cost of the lines. Temperature drops in lines that are not insulated depend on flow rate in the line but for flow rates of 300 GPM and greater, the temperature drop would be on the order of 3-4 degrees Fahrenheit per 1,000 feet of distribution line. The detailed engineering/design study would determine whether or not to insulate the lines. The two technology suppliers are noted below.

- Messersmith Manufacturing, Inc. - www.burnchips.com
- Skanden Boilers - www.skanden.com

Technology and Financial Analysis

Heating buildings at the QIN using biomass for fuel will require addition of equipment to handle the biomass, furnaces and boilers to convert the woody biomass to heat and delivery systems to provide the heat to the buildings. Capital will be required to purchase and install the equipment. This section provides an estimate of the heating load and size of boiler required, a description of possible heating systems and equipment, estimates of the capital and operating costs that would be incurred, and an economic assessment. The economic assessment is used to confirm if heating with biomass provides an economic advantage to the current operation of heating with electricity.

Buildings to be Heated

The buildings that would be heated with biomass are the existing QIN administration building and health center and the planned school and emergency services buildings. The health center is located approximately 1,250 feet from the proposed heating plant site, and the administration complex is located approximately another 1,250 feet beyond the health center. The proposed school and emergency services buildings are estimated to be located within 300-400 feet of the biomass heating plant. All of the administration complex buildings and the health center are currently heated with electricity. The sizes of the buildings are listed in Table 26.

Table 26. Building Size

BUILDING	SIZE (Sq Ft)
Administration complex	59,608
Health center	28,485
School	25,000
Emergency services	14,000

Figure 9 in the Site Review and Selection section of this report displays a preliminary system layout.

Estimated Building Heat Loads

The heat loads for the QIN administration complex buildings and the health center were estimated from the utility electricity bills for the one-year period March 23, 2009 to March 23, 2010. The bills show peak monthly kilowatt demand and monthly kilowatt hours (kWh) use for the buildings. However, all of the electricity use in the monthly bills would not be for heating. Electricity is also utilized as an energy source for lighting, computers, fans, pumps and so on. TSS originally estimated the percentage of the electricity that was used for heat to be 57.5%. This was confirmed by examining the electricity bills which showed a large increase during the winter months where most space heating would occur and the summer months where there would be little space heating. These comparisons indicated that the 57.5% was a reasonable estimate, and the 57.5% was used to estimate the annual heat use of the administration complex and health center buildings.

The heat use projection for the proposed school and emergency services buildings was based on the square footage use of the administration complex buildings, except the use for the emergency services building was increased by a factor of three based on the assumption that it would be in operation around the clock whereas the administration complex buildings would operate primarily during business hours and probably be closed during weekends and holidays. The distance from the central furnace/boiler plant that buildings can be economically served depends on a number of factors including the size of the building load, the difficulty of digging the trench and burying the lines, and the pumping energy required. The distance to the furthest building, 2,500 feet, does not present a problem as far as heat loss goes and the trenching difficulty does not appear to be difficult. However, the elevation difference between the location of the central furnace/boiler plant and the health center and administration complex buildings may increase pumping costs. Again, the detailed engineering/design study would further assess the economic feasibility of serving these buildings. The estimated heat loads for the buildings is presented in Table 27.

Table 27. Estimated Heat Loads

BUILDING	HEAT USE (MM Btu/Yr)
Administration complex	1,660
Health center	1,884
School	697
Emergency services	1,170
TOTAL	**5,411**

Estimated Boiler Size

The biomass boiler must be sized to meet the peak heating demand from the buildings or to about 80% of the peak demand with the remaining 20% made up using the backup heating system. The peak demand was estimated using the minimum monthly temperatures in a typical year and then forecasting to determine the average use per month. These monthly forecasts were then broken into average hourly use based on the number of days in the month. This average use was then multiplied by 1.5 to obtain a peak demand on the boiler of about 1.3 MMBtu/hr. This maximum boiler output is a rough estimate since the actual ratio between peak and average demand is unknown. To be conservative, a peak boiler output of 1.5 MMBtu/hr was assumed (to obtain the estimated capital costs of the two biomass systems analyzed).

Estimated Capital and Operating Costs - Messersmith System

A furnace/boiler by Messersmith (an American company) is automated so that the wood fuel is metered to the boiler depending on the demand for heat. The ash must be removed by hand, but removal would only be required every several days. A 1.5 MMBtu/hr furnace/boiler would meet the heat load for the QIN buildings. Backup for the biomass system could be electric heat, which is already in place in the existing buildings and could be added to the new buildings along with the hot water heating equipment fed by the Messersmith furnace/boiler. This would probably be less expensive than adding an oil-fired backup boiler. However, a detailed engineering design would determine which backup system would be most economical. The estimated installed cost for the Messersmith system based on a quote for the furnace/boiler from Messersmith, including a distribution line to the buildings, lead-in lines to the buildings and building heaters is presented in Table 28.

Table 28. Estimated Capital Cost of a Messersmith System to Supply QIN Buildings

ITEM	COST
Furnace/boiler 1.5 MMBtu/hour	$456,000
Shipping	$30,000
Multiclone	0[38]
Belt conveyor connection and fuel feed	0[38]
Baghouse	0[38]
Pumps/tanks/heat exchanger	$70,000
Automated ash removal	None
Installation	0[38]
Training and startup	0[38]
Electrical	0[38]
Building heating system retrofit	$20,000
Distribution piping (3000 feet)	$180,000
Lead-in piping to buildings (150 feet)	$3,750
Building/civil work	$250,000
Backup heating-electric	$150,000
Engineering	$30,000
Subtotal	$1,189,750
Contingency @ 10%	$118,975
TOTALS	**$1,308,725**

Without a complete engineering design, these costs are conceptual but should be within 10-20% of what would actually be incurred. A complete engineering design might also use a different manufacturer (e.g., Skanden instead of Messersmith or possibly others).

Operating costs incurred with the boiler should be minimal. The boiler would have to be monitored periodically, and this could be performed by existing QIN personnel (see Messersmith operating and maintenance schedule, Appendix F). TSS has therefore not assumed any additional cost for operation. Operator training is included in the capital cost estimate provided by Messersmith and is believed to take no more than a day or two to complete.[39] A list of training items for the Messersmith system is included in Appendix F as a representative example of training needed to operate a small-scale biomass system. There will be maintenance costs, estimated at $2,200/year, based on a maintenance schedule provided by Messersmith, and there may be a cost for property and general liability insurance, which is estimated to be $10,000/year. Ash disposal was assumed to have no associated costs since it can be deposited in the normal waste disposal or spread as soil amendment.[40]

[38]Included in furnace/boiler cost.
[39]Qualifications of an operator for the Messersmith (or other small-scale biomass system) are essentially a mechanically oriented individual.
[40]400 bone dry tons of woody biomass fuel should result in approximately 12 tons of ash per year, assuming an average ash content of 3%.

Estimated Capital and Operating Costs - Skanden System

A boiler by Skanden (a Danish company) is completely automated so that the wood fuel is metered to the boiler depending on the demand for heat (like the Messersmith system), and the ash (with additional capital investment) is automatically removed and deposited in a collection bin. Three, 250 kWh (totaling 0.85 MMBtu/hr) Skanden boilers would meet the heat load for the QIN buildings and by using three, a backup oil-fired boiler would not be required because two of the boilers could meet the peak heating load. The boilers are 8 feet long, 4 feet wide, 8 feet high, and weigh approximately 4,400 pounds. All three of the boilers would be installed in the same central supply building. The estimated installed cost for three of these boilers, including automated ash removal and distribution lines to the buildings, is shown in Table 29.

Table 29. Estimated Capital Costs of Skanden Boilers to Supply QIN Buildings

ITEM	COST FOR THREE BOILERS
Boilers - 853,000 Btu/hour	$357,000
Shipping	$30,000
Multiclone	$32,100
Belt conveyor connection and fuel feed	$27,000
Baghouse	$25,000
Pumps/tanks/heat exchange	$70,000
Automated ash removal	$84,000
Installation	$9,000
Training and startup	$20,000
Electrical	$6,000
Building heating system retrofit	$20,000
Distribution piping (3,000 feet)	$180,000
Lead-in piping to buildings (150 feet)	$3,750
Building/civil work	$250,000
Engineering	$30,000
Subtotal	$1,143,850
Contingency @ 10%	$114,385
TOTALS	**$1,258,235**

Without a complete engineering design, these costs are conceptual but should be within 10-20% of what would actually be incurred. A complete engineering design might also use a different manufacturer (e.g., Messersmith) than Skanden.

Operating costs incurred with the boiler should be relatively minimal. The Skanden system would have to be monitored periodically, and existing QIN personnel could perform this. TSS has therefore not assumed any additional cost for operation. Operator training is included in the above estimate and is believed to take no more than one to two days to complete (similar to the Messersmith training as detailed in Appendix F). However, there will be maintenance costs, estimated at $5,000/year, based on information previously provided by Skanden, and there may be a cost for property and general liability insurance, which is estimated to be $10,000/year. Ash disposal was assumed to have no associated costs since it can be deposited in the normal waste disposal or spread as soil amendment.

Estimated Economic Feasibility of Biomass Heating

To estimate the economic feasibility of converting the existing administration complex buildings and health center and to provide heating to the proposed school and emergency services buildings, TSS employed a discounted cash flow model. This model uses the difference in fuel costs (in this case between biomass and electricity) and compares this savings with the additional costs of installing and operating the biomass-fired heating system. The current cost of electricity appears to be 6-7 cents/kWh based on kWh usage by the administration complex buildings and health center (as provided by QIN staff). Using 7 cents/kWh, the equivalent heating cost would be $20.51/MMBtu and the cost of biomass fuel would be $2.74/MMBtu based on a fuel heating value of 8,200 Btu/dry lb. and a price of $45/BDT.

The savings from the difference in electricity and biomass fuel costs to heat the buildings ($17.77/MMBtu) is shown as revenue in the cash flow model, and the costs of wood fuel are shown as an expense. Also shown as an expense are the maintenance and insurance costs.

The method by which the project would be financed is unknown. The following financing plans were therefore investigated:

- All equity capital provided by the QIN.
- Fifty percent of the capital provided by QIN and the remaining 50% financed with 20-year debt with an interest rate of 5%/year.[41]
- Fifty percent of the capital provided by QIN and the remaining 50% financed by a federal or state grant.
- Twenty percent of the capital provided by QIN and the remaining 80% financed by a federal or state grant.
- Project financed 100% with grant funds.

Economic Feasibility of Messersmith System

Table 30 lists the values used as inputs to the discounted cash flow model.

[41]Five percent (5%) interest rate could be obtainable by the QIN.

Table 30. Messersmith System Financial Analysis Inputs

INPUT PARAMETER	VALUE
Capital cost	$1,308,725
Heat produced-MMBtu/year	5,411
Fuel cost ($/BDT)	$45
Boiler efficiency (%)	80
Cost difference-electric – biomass ($/MMBtu)	$17.77
Maintenance cost/year	$2,200
Insurance cost/year	$10,000
FINANCING:	
All QIN equity	
Fifty percent QIN equity, 50% debt @ 5%	
Fifty percent QIN equity, 50% grant funds	
Twenty percent QIN equity, 80% grant funds	
One hundred percent grant funds	

The results for the four capital financing cases are shown in Table 31.

Table 31. Messersmith System Financial Analysis Results

CASE	NPV	ROE
All QIN equity financing	-$782,087	0.00%
QIN equity 50%; debt of 50% at 5% interest rate	-$498,870	Less than 0
QIN equity 50%; grant for 50%	-$213,075	7.70%
QIN equity 20%; grant for 80%	$128,331	24.7%
All grant funds	$355,935	NA

The two best indicators of economic feasibility for a proposed project are net present value (NPV) and return on equity (ROE). The NPV method discounts the expected net cash flows from the project using the owner/investor's required return on investment to the beginning of the project, sums them, and subtracts the capital investment outlay to provide the NPV of the project. If the NPV is positive, the project will increase the wealth of the owner or investor and is therefore acceptable. If the NPV is negative, the owner's wealth will be decreased, and the project should not be undertaken.

The ROE method determines the discount rate that equates the expected net cash flows from the project to the capital contributed by the owner or investor. If the determined ROE is equal to or greater than the ROE the owner or investor believes they should receive, the project is considered to be acceptable. If the ROE is less than what the owner should receive, the project is not acceptable and should not be undertaken.

These two methods (NPV and ROE) should provide the same project accept/reject result. Other methods, such as payback period, are not as theoretically sound or as accurate as the NPV and ROE methods.

This type of project should provide an ROE of 10-15% or an NPV of zero or greater to be considered economically feasible. For the 100% QIN and 50% QIN, 50% debt financing cases, the project is not economically feasible. The project is still not feasible if a grant for 50% of the project capital could be obtained since the ROE of 7.7% is less than the 10-15% considered acceptable for projects such as these. If the project could be financed with an 80% grant, it would provide an NPV of $128,331 or 24.7% ROE. Not surprisingly if 100% grant is available, it would be very feasible since it provides an NPV of $355,935 to the QIN (ROE is not relevant since QIN would not have any equity invested in a 100% grant scenario).

Economic Feasibility of Skanden System

Table 32 lists the values used as inputs to the discounted cash flow model.

Table 32. Skanden System Financial Analysis Inputs

INPUT PARAMETER	VALUE
Capital cost	$1,258,235
Heat produced (MMBtu/year)	5,411
Fuel cost ($/BDT)	$45
Boiler efficiency (%)	80
Cost difference-electric – biomass ($/MMBtu)	$17.77
Maintenance cost/year	$5,000
Insurance cost/year	$10,000
FINANCING:	
All QIN equity	
Fifty percent QIN equity, 50% debt @ 5%	
Fifty percent QIN equity, 50% grant funds	
Twenty percent QIN equity, 80% grant funds	
One hundred percent grant funds	

The results for the four financing cases are shown in Table 33.

Table 33. Skanden System Financial Analysis Results

CASE	NPV	ROE
All QIN equity financing	-$753,423	0.00%
QIN equity 50%; debt of 50% at 5% interest rate	-$481,132	Less than 0
QIN equity 50%; grant for 50%	-$206,363	7.70%
QIN equity 20%; grant for 80%	$121,871	24.6%
All grant funds	$340,695	NA

Like the Messersmith financial analysis, 100% QIN and 50% QIN, 50% debt financing cases, the project is not economically feasible since they show large negative NPVs. The project is still not economically feasible if a grant for 50% of the project capital could be obtained since the ROE of 7.7% is less than the acceptable return of 10-15% for projects of this kind. If the project could be financed with an 80% grant it would be very feasible with an NPV of $121,871 and an ROE of 24.6%. At 100% grant, it would be very feasible since it would provide an NPV of $340,695 to the QIN.

The two systems, Messersmith and Skanden, are basically equal with regard to economic feasibility, and either system could be used. Selection would depend on final estimates submitted by the two companies and the preference of QIN. The principal limiting economic factor for the establishment of biomass thermal unit as described previously is the lack of economic feasibility if grant dollars are not available for more than 50% of the financing of the system.

Estimated Annual Savings Wood Heat vs. Electric Heat

Only the 80 and 100% grant cases are economically feasible as shown in Tables 31 and 33 above. Achievement of the 80% grant case is probably more likely than a 100% grant and the 80% grant case has been selected to estimate the annual savings from using wood fuel for heat instead of heating with electricity. Table 34 below shows the estimated savings for heating both existing and proposed buildings with wood fuel.

Table 34. Estimated Savings From Heating with Wood Fuel-80% Grant[42]

ESTIMATED SAVINGS BY HEATING EXISTING BUILDINGS WITH WOOD					
EXISTING BUILDINGS	ELECTRICITY USAGE (kWh/Yr)	ELECTRICITY COST ($/kWh)	COST ($/Yr)	HEAT REQUIRED (MMBtu/Yr)	PERCENT OF TOTAL HEAT[43]
Administration Complex	846,240	0.07	$59,237	1,661	31%
Health Center	959,760	0.07	$67,183	1,884	35%
TOTAL	**1,806,000**		**$126,420**	**3,545**	**66%**
Total Wood Heating Cost[44]			$72,576		
Existing Buildings Heating Cost			$47,548		
Savings			**$78,872**		
PROPOSED BUILDINGS					
School	204,095	0.07	$14,287	697	13%
Emergency Services	342,814	0.07	$23,997	1,170	22%
TOTAL	**546,909**		**$38,284**	**1,867**	**35%**
Total Wood Heating Cost			$25,041		
SAVINGS			**$13,242**		
EXISTING AND PROPOSED BUILDINGS					
TOTAL SAVINGS			**$92,114**		

Table 34 shows a savings of $78,872 per year by utilizing wood heating for existing buildings as opposed to heating with electricity. Table 34 also shows a savings of $13,242 per year for proposed buildings (wood heat compared to electric), resulting in an estimate of total savings of $92,114 per year.

Regarding operational needs of either system (and most likely other systems as well), the small size of the facility, lack of high pressure steam boiler involved, and relatively small amount of biomass fuel input (see Table 25) does not result in significant additional employment opportunities. Depending on the system selected, it may even be possible to utilize existing QIN employee(s) to operate the biomass thermal system. However, additional employment opportunities for QIN exist in collecting, processing, and transporting the excess biomass materials generated by QIN and BIA forest operations. The 14,000-plus BDT (see Fuel

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[42] Messersmith facility with grant of 80% with 20% equity and fuel cost of $45/BDT.
[43] Total heat for existing and proposed buildings is estimated to be 5,4011 MMBtu/Year.
[44] The total wood heating cost is for both existing and proposed buildings.

Availability discussion) could employ five to eight individuals in jobs such as equipment operators, truck drivers, and operations supervision.

Thermal Energy Operators Interview Results

Three operators of small-scale thermal installations utilizing woody biomass fuel were contacted to solicit observations regarding experiences with specific biomass fired heating systems. These operators manage combustors that utilize chipped woody biomass as the primary feedstock. Operators were selected because their heating systems best exemplify the proposed thermal energy project for the QIN based on the scale of their operation, geographic location, and primary feedstock type. Their responses have been categorized into five sections: Buildings Served, Equipment Purchased and Installed, Feedstock, Financials, and Operations.

Buildings Served

All of the respondents use their combustion and boiler system to heat small school district buildings ranging in size from 88,000 to 200,000 square feet. These systems all employ closed-loop systems where wood chips are burned in a combustion unit to heat water in a boiler. The hot water or steam conveys the heat through the building to deliver heat through radiators. These systems consumed between 900 and 3,000 green tons (450 to 1,500 BDT based upon 50% moisture content) of woody biomass feedstock per year to generate 3.3 million Btu to 6.5 million Btu of heat per hour. Each installation is a retrofit replacing fuel oil boilers.

For each unit, the majority of the heat transfer infrastructure was already in place and did not require significant investment in additional equipment. While all of the operators prefer the woody biomass-based central heating system that they currently operate, each operator noted that the cost of retrofitting buildings without the infrastructure for a steam or working-fluid based heating system, as described above, would likely be cost prohibitive.

Equipment Purchased and Installed

For all of the operators interviewed, the entire system as installed was purchased from the technology vendor. The purchase included the combustion technology, boiler system, fuel bins, fuel processing and handling systems, and air emissions control systems. In each of the installations, some components were sourced from other companies through the technology vendor (e.g., boiler and emission control systems). In each scenario, the technology vendor installed the system on-site and a general contractor was selected to connect the new thermal system to the old building infrastructure and construct the building housing the equipment.

While no operation was flawless upon initial operation, each operator expressed satisfaction with the technology vendor’s warranty, performance guarantee, and support. Each operator noted the importance of these warranties and performance guarantees because they each experienced issues over the first few months of operation requiring post installation work from the technology vendor. A quality, reliable technology vendor was very important to minimize additional costs as the system was placed into commercial service.

For each system, water consumption was minimal (less than 500 gallons per year), typically only to replenish the steam used for heating. Each combustion unit used the moisture content of the feedstock to control combustion temperatures with a quoted optimum of 30% moisture and a practical range between 18% and 40%. Operators noted the importance of staying within these constraints to maintain operational efficiency and minimize maintenance costs. Feedstock with greater moisture content should be mechanically dried (e.g., rotary drum drier) or stored in a covered and ventilated area to allow for natural drying. The means for reducing the moisture content will depend on the availability of fuel storage space. Alternatively, forest biomass material can be seasoned in raw form in the woods and processed once it has dried naturally. Depending on weather conditions, drying in raw form could take up to one year.

If the moisture content is too high, the combustion unit will not maintain sufficiently high temperatures for efficient combustion. For feedstock with low moisture content, water or high moisture content feedstock should be mixed before combustion. Moisture is used to regulate the combustion temperature to maintain sufficiently low combustion temperatures to avoid the creation of clinkers from the gasification of minerals and ash. For each system, there was no water effluent (wastewater) generated.

The air emission control devices varied widely by geography. All of the systems included a cyclone (there were varieties within cyclone type) to control fly ash emissions and particulate matter.[45] Some installations required additional baghouses or electrostatic precipitators to meet local air emissions requirements. In all cases, the technology vendor worked directly with the clients to develop, purchase, and install appropriate emission control systems. Each operator successfully complied with annual air emissions testing.

The feedstock storage and handling configuration varied greatly for each system. Many of the operators had trouble initially with their feedstock conveyance systems. In one case, the technology vendor returned to the site to install a new system to meet the client's needs. Several operators noted that a below grade fuel storage system simplified the operations process and the fuel loading. The below grade fuel storage system that was described by the operators was a fuel storage bin placed in the ground (as opposed to on the ground). The below grade fuel storage system used a live floor auger system (similar to above grade fuel storage systems). The advantage to the below grade fuel storage bin is that a fuel storage truck can pull up to the top of the bin and unload directly into the bin while the system continues to operate. In an on-grade system, the fuel storage bin must be near empty to provide space for unloading and the auger must be off to allow for the chip truck to drive over it. The below grade system allows for greater flexibility for fuel delivery and minimizes strain on the conveyance equipment.

Feedstock

The feedstock handling equipment specifications were found to have the most profound impact to the successful operation of the thermal system. All operators were satisfied with the engineering of the equipment but noted that deviations in delivered fuel from the prescribed

[45] Particulate Matter (PM) is classified as course (meaning the particulate diameter is greater than 10 microns – PM10) or fine (meaning the particulate diameter is between 2.5 and 10 microns – PM2.5). PM emissions are regulated in most air sheds. Most differentiate between PM2.5 and PM10.

feedstock specifications greatly affected the overall system performance. For the combustion devices, the moisture content of the fuel was optimally 30% to 35%, but operators noted a working range from 18% to 40%. It was unnecessary for operators to carefully monitor moisture content when using feedstock within this range.

Each operator used slightly different feedstock material but sourced primarily local softwood and hardwood chips with an energy value (high heating value) between 6,000 Btu/lb and 7,000 Btu/delivered dry pound. Because of the high cost of fuel oil (the alternative heat source for each of the projects), the purchase price for woody biomass feedstock was not an important constraint. Delivered feedstock prices ranged from $20 per green ton to $55 per green ton ($40 to $110 per BDT at 50% moisture content). Even at these relatively high prices, the financial analysis yielded significant annual savings. Each operator had experience with variations in feedstock (e.g., fuel sizing, moisture, heat value) and always found the technology vendor's specifications to be the most appropriate to assure efficient operation. The technology vendors typically specified clean,[46] three inch minus chips preferably from whole tree chipping operations or sawmill byproduct.

In several systems, the operators experimented with processed fuel from forest operations and found that contaminants from dirt and rock generated excessive ash quantities with high heat capacities, resulting in difficulties maintaining constant combustion temperature. Additionally, minerals from bark and leaves at high temperatures create slag and clinker residue within the boiler requiring temporary shutdown of the combustion system for additional maintenance. Maintenance and unit downtime, and therefore costs, increase significantly when using such feedstock as opposed to operating with clean wood chips or adhering to the technology vendor feedstock specifications.

The operators did not find that the chips needed to be completely bark-free for proper operations. The existence of bark and needles or leaves in the feedstock was not detrimental as long as the proportions were not high. Several of the operators produced their own chips from whole trees. These operators rough handled the trees to remove as many leaves or needles as possible but did not remove the bark. None of the operators used feedstock processed through grinders, preferring chippers to process the fuel to more uniform chip size. However, some of the manufacturers have worked with feedstock processed with grinders and recommend two inch minus to allow for better flow. It is critical to specify the feedstock supply source during preliminary system design and engineering to determine compatibility with vendor equipment.

Financials

The operators that were interviewed all expressed satisfaction with the capital costs and project installation costs for the project. Each expressed a short payback period due to the high (and fluctuating) cost of fuel oil. All noted that the transportation costs for equipment delivery were included in the original system price and none of the operators experienced any cost overruns. Total capital costs ranged between $900,000 and $1,500,000. The cost of equipment and system installation comprised between 50% and 66% of the total cost. The balance was used to connect the system to the existing heat transfer infrastructure and for equipment housing.

[46] "Clean" chips refers to chipped product, hardwood or softwood, that is free of bark.

All of the projected operating and maintenance costs were found to be accurate so long as the appropriate feedstock (per vendor's specifications) was used. Many operators found higher operational costs in the first few months of operations due to experimentation with feedstock types that ultimately resulted in additional maintenance costs. Typical labor costs for personnel of the facilities were around $1,000 per year. Note that these facilities all used low pressure steam boilers and do not require an onsite boiler operator.

Operations

Each operator used internal (already on site) personnel to operate the facility. The system requires at least one staff member to be a certified steam boiler operator, and each of the facilities already had appropriately qualified staff since they previously operated fuel oil based steam boilers. There is a distinction between low and high pressure steam operating licenses. License requirements vary from state to state, but all operators noted that the training can be challenging but is not unnecessarily long or difficult.

Each operator had a detailed operations manual provided by the technology vendor and was also provided with on-site training from a representative of the technology vendor. Commissioning was also provided by the technology vendor, and none of the operators had to purchase additional equipment after commissioning.

For the operators interviewed, typical daily maintenance consisted of 15 minutes or less of cleaning ash from the combustor. Ash needs to be removed from the combustion unit each week, and fly ash needs to be removed from the cyclone on a quarterly basis. Ash collection was approximately 20 gallons per 23 green tons (11.5 BDT at 50% moisture content); burned and fly ash amounted to approximately 15 gallons per quarter. When using lower-quality feedstock, slag and clinker material needed to be removed almost daily and required a full shutdown of the facility. The ash cleaning does not require a full shutdown and can be accomplished by temporarily halting the burn. Note that a temporary halt in the burn is applicable to thermal generation only, not for electric generating facilities (e.g., combined heat and power). The ash could be used as fertilizer, but for facilities without the appropriate storage capacity, ash was cooled and disposed of with the trash.

Each operator indicated that the technology vendor was particularly helpful and quick to respond to operational questions. The technology vendor worked with the operators at critical operational junctures such as during experimentation with different feedstock mixes and as the air emission control devices were commissioned.

Interview Highlights/Lessons Learned

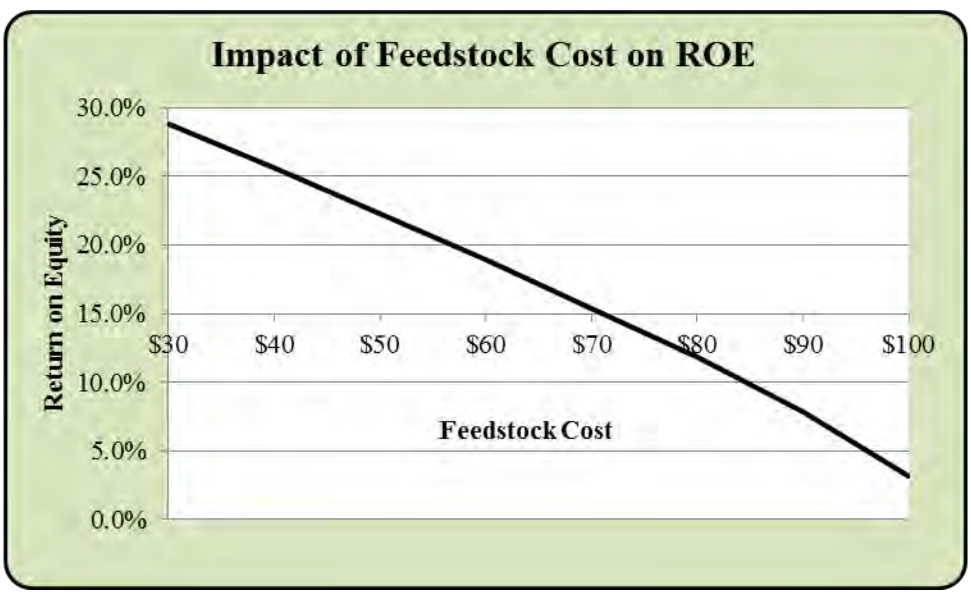
- Retrofitting buildings for thermal energy conveyance systems is often cost prohibitive.
- For remote regions, on-site versus off-site fabrication is important.
- Reliable technology vendors with experience are important for troubleshooting and commissioning, especially in the early stages.
- Water consumption and discharge is not an issue with these combustion systems.

- Air emissions controls are a small, but potentially significant part of the total cost and can be engineered to meet local air quality restrictions.
- Proper fuel is the most important aspect.
  - Moisture content should be within the technology vendor's specifications.
  - Excess bark and needles or leaves can create slag and clinkers that greatly increases operational and maintenance costs and downtime.
  - Consistent sizing is critically important. Typically 3" minus is ideal, but 4" minus has not been a problem when processed with a chipper. The important factor is consistency in material flow.
  - Consistent heat density (high heat value) is important.
- Payback is heavily dependent on the delivered woody fuel price and the replacement fuel price (e.g., fuel oil).
- Operation and maintenance costs are low when using vendor specified feedstock but can greatly increase with different feedstock.

Feedstock Cost Sensitivity

The graphs below (Figures 14 through 17) show the impact of changes in feedstock price ($/BDT) in $10 increments to various financing alternatives for both the Messersmith and Skanden thermal energy systems. The ROE and NPV data used in these analyses were derived from the pro forma cash flow model used in the financial analyses for each system. Figure 14 shows the impact of changes in feedstock prices on ROE for a finance scenario of 50% grant, 40% debt and 10% QIN equity for the Skanden thermal energy system.

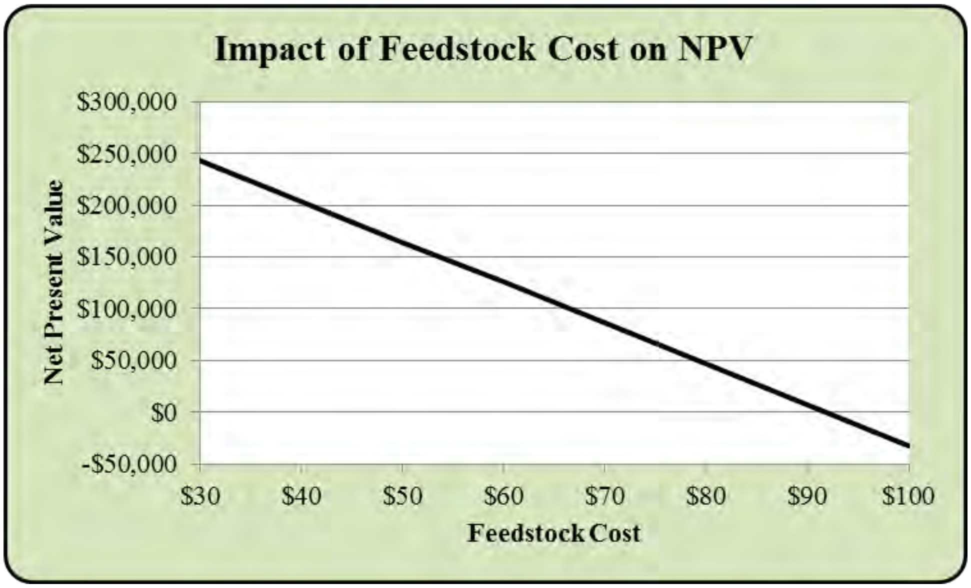
Figure 14. Skanden 50% Grant, 40% Debt, 10% Equity Financing Option



The baseline ROE for a favorable outcome would be 15%. In Figure 14 above, the X-axis is set at 15% indicating that as feedstock prices approach just over $70 per BDT, the economic outcome is unfavorable.

Figure 15 shows the impact of changes in feedstock prices on NPV for a finance scenario of 50% grant, 50% debt and 0% QIN equity for the Skanden thermal energy system. ROE is an invalid metric since there is no equity under this scenario.

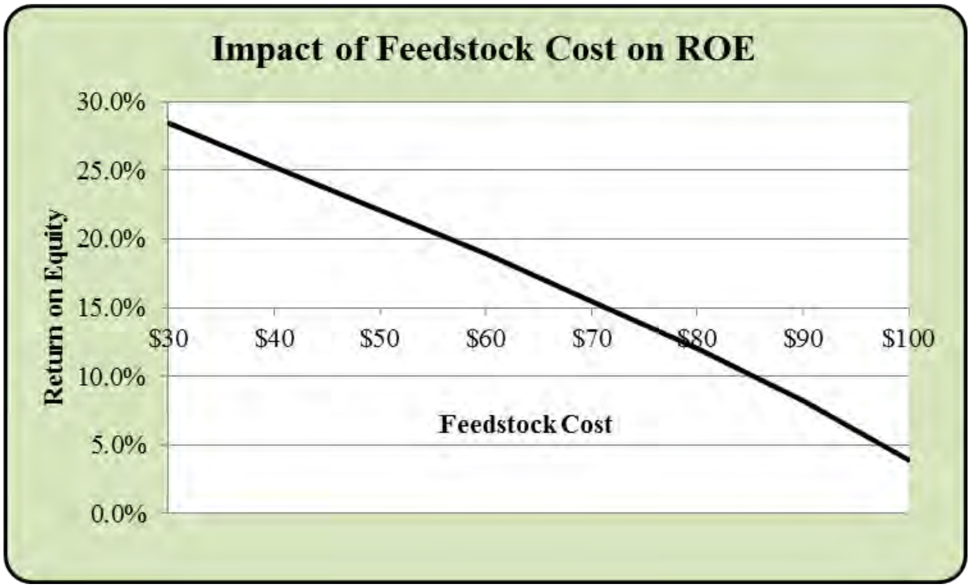
Figure 15. Skanden 50% Grant, 50% Debt, 0% Equity Financing Option



The results in Figure 15 indicate a positive NPV under this finance scenario until feedstock prices approach just over $90 per BDT.

Figure 16 shows the impact of changes in feedstock prices on ROE for a finance scenario of 50% grant, 40% debt and 10% QIN equity for the Messersmith thermal energy system.

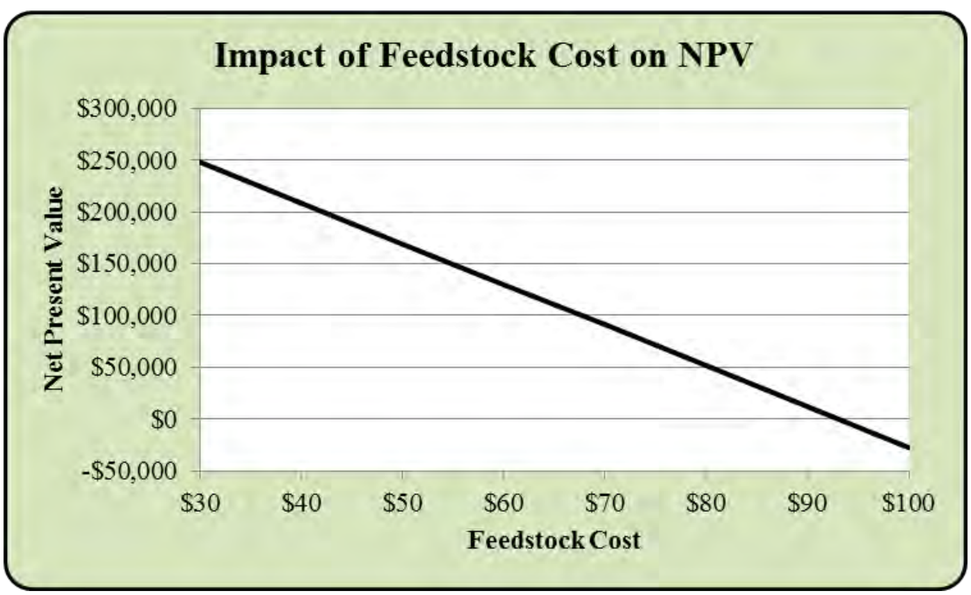
Figure 16. Messersmith 50% Grant, 40% Debt, 10% Equity Financing Option



The baseline ROE for a favorable outcome would be 15%. In Figure 16 above, the X-axis is set at 15% indicating that as feedstock prices approach just over $70 per BDT, the economic outcome is unfavorable.

Figure 17 shows the impact of changes in feedstock prices on NPV for a finance scenario of 50% grant, 50% debt and 0% QIN equity for the Messersmith thermal energy system. ROE is an invalid metric since there is no equity under this scenario.

Figure 17. Messersmith 50% Grant, 50% Debt, 0% Equity Financing Option



The results in Figure 17 indicate a positive NPV under this finance scenario until feedstock prices approach just over $90 per BDT.

The results for both thermal energy systems are very similar with only minor differences in outcome. The difference in the capital cost of these systems amounts to only $50,000 or 4%, hence the similarities in results for these analyses.

CONCLUSIONS

There is sufficient feedstock to fulfill the woody biomass feedstock requirements for a thermal energy facility for the three buildings subject to relocation at Taholah, as well as the existing Administration and Health Center buildings. In fact, these facilities are estimated to use only 400 BDT of woody biomass fuel per year. Forest harvest operations on the reservation, from both QIN and BIA operations, will generate, in terms of gross volume, an estimated 33,750 BDT per year. However, some of this volume would be very expensive to recover and perhaps be cost prohibitive for current biomass markets or for value-added alternatives.

Both the Messersmith and Skanden technologies are solid, dependable, and suitable for deployment in a thermal energy application at Taholah. Messersmith has more units in service throughout the U.S. and especially in the western states. Discussions with current owner/operators indicated complete satisfaction with their biomass burning heating units. Most issues with regard to either operations or maintenance were the result of deviating from recommended feedstock specifications. The technologies are similar in equipment acquisition and installation cost. The economic analysis for either is not favorable without substantive grant contribution. Given the number of units in operation in the western U.S. and the experience of Messersmith with regard to the various types of feedstock used in their units, TSS would recommend their technology as best suiting the thermal energy needs for QIN at Taholah.

The thermal energy technology as well as the value-added alternatives have well defined feedstock specifications. These technologies best function when adhering to their respective feedstock specifications. The thermal energy systems function most effectively when using a consistently sized feedstock and preferably clean or dirty chips (chips with some bark). Some of the operators using similar or identical technologies to those considered for QIN actually procure whole logs and conduct on-site chip operations for their feedstock needs.

Results of this analysis indicate that perhaps the most appropriate business model for recovering biomass from forest operations upon the reservation may require chipping and screening to develop feedstock of suitable characteristics. Other alternatives are to acquire clean wood product manufacturing byproduct for the thermal energy facility, or set aside low-grade pulp logs from QIN harvest operations and contract the chipping and delivery to the facility. The latter alternative might require the ability to store 100 BDT of chips if this operation was performed quarterly.

The value-added alternatives (firewood substitutes and CHP) would also generate better products with better quality raw material. Small-sized (3/4” to 2”) chipped material with minimal contaminant as well as needles, leaves and twigs is the preferred feedstock. Also, moisture content below 15% is important, and therefore drying equipment would be required. Since the drying equipment would use moist (50%) woody biomass material to operate, rather than natural gas, the cost could be from $500,000 up to $1,500,000. Though the CHP facility would not require chipped material, this feedstock is typically of better quality for use in small systems, both for combustion and conveyance.

The problem with acquiring equipment for chipping product to the specifications above is that it would not serve a biomass recovery production operation developed for marketing product to large, industrial boilers (such as those used in the pulp and paper and wood products manufacturing facilities). The chipping equipment is typically slower in production volume per unit of time and requires increased maintenance and therefore more downtime than large-scale tub or horizontal grinders. An additional alternative may be acquisition of a horizontal grinder with the ability to replace parts used for grinding woody biomass with blades used for chip production. If QIN elected to develop an enterprise focused upon recovery of biomass from their forest operations, a decision with regard to the “best fit” business model would be required, with commensurate trade-offs in terms of cost and benefits.

The most effective solution for a QIN enterprise focused upon recovery, processing and delivery of woody biomass from forest operations on the reservation would be a commercial-scale operation focused upon production of material suitable for both the thermal energy system as well as larger, industrial boiler operations as the primary alternative market. Unfortunately, feedstock for the larger, industrial boiler is unsuited for the thermal energy system. In the current regional market, the result of the closure of Grays Harbor Paper is the loss of the primary customer for biomass from forest operations. The other operators of wood-fired boilers do not currently use material from forest operations as feedstock. However, if the company that recently signed a letter of intent to acquire the Grays Harbor Paper facility initiated operations of the power island, a QIN forest-sourced biomass processing enterprise could have a primary customer. The most prudent business model would be to secure, at minimum, a five-year supply contract before considering such an enterprise. QIN should also contact adjacent landowners to assess biomass recovery opportunities on their ownerships to support the prospective enterprise. The small feedstock volume necessary for the thermal energy system (400 BDT per year) would not warrant initiation of an enterprise solely to produce feedstock suitable for its operation; there are other, more cost effective alternatives (such as procuring sawmill residuals as fuel).

None of the value-added alternatives reviewed for this study are without significant capital costs. Residential fuel pellets are produced with clean byproduct of wood products manufacturing (e.g., dry shavings). Using forest-sourced material as a raw material would produce a pellet with significant ash content and be quickly identified as an inferior product. Densified firewood substitutes can use forest-sourced material as feedstock; however, drying and screening would be necessary, which also increases capital costs. The small, community-scale power plant, sized to meet the electricity needs of Taholah, could use properly processed forest-sourced material but would also require drying. These facilities all cost between $2 million to as much as $4.5 million, depending upon equipment condition (new or used). The feedstock needs for these enterprises range from as low as 4,500 BDT to 15,000 BDT per year.

APPENDIX A POTENTIAL GRANT FUNDING RESOURCES

TSS conducted a literature search for grant and loan support targeting small-scale bioenergy projects. Outlined below are the results.

Rural Energy for America Program (REAP)
Administered by the USDA Rural Business-Cooperative Service, this program replaced the Renewable Energy Systems and Energy Efficiency Improvements program in the 2002 farm bill. The program provides grants and loans for a variety of rural energy projects, including efficiency improvements and renewable energy projects. Assistance is limited to small businesses, farmers and ranchers with projects located in a rural community. REAP grants and guarantees can be used individually or in combination. Together the grants and loan guarantees can finance up to 75% of a project's cost. Grants alone can finance up to 25% of the project cost, not to exceed $500,000 for renewables and $250,000 for efficiency.

Woody Biomass Utilization Grants
Administered by the USFS, the Woody Biomass Utilization Grant program (WBU) is a nationally competitive grant program that supports wood energy projects requiring engineering services. The projects use woody biomass material removed from forest restoration activities, such as wildfire hazardous fuel treatments, insect and disease mitigation, forest management due to catastrophic weather events, and/or thinning overstocked stands. The woody biomass must be consumed in a bioenergy facility that uses commercially proven technologies to produce thermal, electrical or liquid/gaseous bioenergy. Maximum grant is $250,000.

Biomass Research and Development Initiative
Administered by the US Department of Agriculture and the US Department of Energy. Both agencies produce joint solicitations each year to provide financial assistance in addressing research and development of biomass based products, bioenergy, biofuels and related processes. Approximate funding per project is $7,500,000.

Business and Energy Guaranteed Loans
Administered through the US Department of Agriculture. To improve, develop, or finance business, industry, and employment and improve the economic and environmental climate in rural communities.

APPENDIX B PROJECT DESCRIPTION

(Prior to issue of Augmented Scope of Work)

Introduction

The Quinault Indian Nation (QIN) is investigating the utilization of forest biomass material as fuel for heating three proposed Tribal facilities. These new facilities include a school (currently under construction), community center and the emergency services /jail/courthouse. Plans for the community center and the emergency services /jail/courthouse are in the very early stages of development however there is considerable interest in the use of renewable and under-utilized resources (woody biomass) to provide thermal energy. Two key reasons for the QIN to consider this project include:

- The need to relocate existing community buildings to a safer location above the tsunami evacuation zone and away from potential storm damage. The December 2007 storm severely impacted the seawall that has protected community facilities for over 20 years. The QIN have selected a 110 acre target site near the community of Taholah for relocation of these facilities. This site is above the flood plain and tsunami zone.

- Ready availability of under-utilized forest biomass currently generated on the reservation. Significant quantities of timber harvest byproducts are generated annually.

Project Goals

The primary driver for this feasibility study is the need to address alternatives to disposal of forest slash as well as taking advantage of the opportunity to consider alternative, environmentally appropriate heating technologies as new community facilities are being planned. Experience has shown that engineering and installing biomass fired thermal heating systems is much more cost effective in the early phases of new building design as opposed to refurbishment of existing facilities. In addition, utilization of forest slash for prospective a renewable thermal energy project on the QIN reservation will generate new family-wage employment opportunities.

Specific goals for this feasibility study include:

- QIN self-reliance through utilization of on-reservation energy sources.
- Environmental stewardship/forest health improvement.
- Forest operations byproduct utilization.
- Community economic development.
- Job training, creation and retention.
- Renewable energy project development.

Thermal Energy Projects

In recent years many communities have converted existing fossil fuel fired thermal energy systems to biomass fired units. The technology to effectively convert biomass fuel to thermal energy is robust, dependable and fairly simple to operate and maintain. A major motivating factor is the opportunity to replace non-renewable fuels such as fuel oil, natural gas and propane with a renewable fuel. While natural gas prices are currently low (<$4.50/million BTU), this is a relatively new phenomenon and gas prices are likely to remain volatile.

Currently there are over 100 separate biomass fueled thermal energy systems installed at schools and community buildings throughout the United States.[47] The ready availability of biomass material from forest thinning, timber harvest and forest products manufacturing operations in rural areas of the United States has facilitated development of projects in mostly small rural communities.

Target Study Area

The QIN reservation includes 208,150 acres of highly productive forestland that is actively managed. Significant quantities of timber harvest byproducts in the form of limbs and tree tops (collectively known as slash) are generated annually. Currently much of this slash is piled and burned on site. In recent years the QIN have entered into an informal agreement with Grays Harbor Paper for the collection and removal of much of slash for use as fuel in a cogeneration facility. It is anticipated that forest slash resources will provide a sustainable and cost effective source of fuel long term. The target study area for the purposes of this feasibility study is the QIN reservation. Figure 1 below highlights the location of the reservation.

Figure 1. Target Study Area – QIN Reservation

[47] Personal communication with Dave Atkins, Wood Biomass Program Manager, Regions 1 and 4, USDA Forest Service.

Fuel Types Considered

The primary fuel source considered for this feasibility study will be woody biomass material available from forest management activities conducted on the QIN reservation. These include timber harvest, pre-commercial thinning, fuels treatment, and salvage logging activities and other raw/woody biomass waste. Other woody biomass available from local sawmills and from construction/demolition and tree trimmings will also be considered.

As stated earlier, the primary method used for disposal of excess biomass from forest operations is pile and burn or allowing entities such as Grays Harbor Paper to collect and transport material off the reservation. Other value added alternative uses include:

- Soil amendment
- Firewood
- Landscape cover
- Erosion control/Soil stabilization

Project Deliverables

The feasibility study is scheduled for completion no later than September 1, 2011. At that time a complete feasibility study report will be delivered, followed by a presentation of findings. (The Augmented Scope of Work revised to due date to January 2012.)

APPENDIX C BIOMASS VOLUME AND PRICE MODEL ASSUMPTIONS WORKSHEET

The Assumptions Sheet shows the assumptions that have been assumed throughout this model. Any of the assumptions in white cells can be changed. The hourly rates below include the cost of ownership, labor, and profit & risk at 10% to 15%.

EQUIPMENT TYPE	EQUIPMENT RATE ($/hr)	MOBILIZATION
Horizontal Grinder	$350	Yes
Tub Grinder	$350	Yes
Horizontal Chipper	$350	Yes

EQUIPMENT TYPE	EQUIPMENT RATE ($/hr)	MOBILIZATION
Skidder	$85	Yes
Cat D5, D6	$90	Yes
Lowbed standard	$100	No
Lowbed heavy	$125	No
Grader	$85	Yes
Mech Truck	$20	No
Water Truck	$60	No
Crew Vehicle	$20	No
Loader/Shovel/Excavator	$125	Yes
Front End Loader (Rubber tired)	$80	Yes
Off Highway Dump Truck	$100	Yes

CHIP VAN SIZE	VAN TYPE	GT CAPACITY
26'	tandem possum belly	15
28'	tandem possum belly	17
32'	tandem possum belly	19
40'	live floor	22
45'	live floor	25
45'	live floor	26
48'	live floor	27
48'	live floor/belt drive	30
48'	possum belly	29
53'	possum belly	33
53'	live floor	30

On Highway Diesel Price Benchmarked to Local Retail Prices	$3.90	$/gal

USER INPUT WORKSHEET

The User Input Sheet is designed to compile all of the specifics of a particular operation. Each table represents a distinct aspect of woody biomass collection. Adjustments on the user inputs may affect the outputs in the Results Sheet. Any white cell should be filled in by the user. These are the only cells available for selection. If text appears in the corresponding notes section of any input, there is an error with the inputs.

Timber Harvest Estimate

	Inputs	Units	Notes
Timber Harvest Volume	1000	MBF	
Biomass Recovery Factor	0.9	BDT/MBF	
Moisture Content	50.0%	Percentage	
Percent Unit Accessible	50%	Percentage	
Percent Unit Tops or Whole Tree Yarded	100%	Percentage	
Pulp Logs Removed?	Yes No		
Chunkwood Removed?	3		

Use The Tim

Pile Estimate

	Inputs	Units	
Pile Input	1000	GT	
Moisture Content	50.0%	Percentage	

Use the Pile Esti

Select one Estimation Method and fill in the cooresponding inputs.

USER INPUT WORKSHEET CONTINUED

Equipment Mobilization Transportation Estimate			
	One-Way Distance (miles)	Average Speed (mph)	Notes
Highway	0	65	
Non-Highway Roads, Paved	30	40	
Unpaved Roads	10	20	
	Input	Units	Notes
Lowbed Transportation Cost	97.5	$/hour	
Equipment Loading Time	0.33	hours	
Equipment Unloading Time	0.33	hours	
Total Round Trip Time	3.16	hrs	

USER INPUT WORKSHEET CONTINUED

Equipment List								
Select Equipment from the Drop Down Lists		Quantity (# of Units)	Equipment Production (BDT/Hour/Unit)	Scheduled Hours (hr/day)	Productive Hours (hr/day)	Utilization Rate (%)	Adjusted Production (BDT/hr/Unit)	Notes
Grinder or Chipper								
Horizontal Grinder	2	1	30	8	6	0.75	22.5	
Other Equipment								
Loader/Shovel/Excavator								
Crew Vehicle	10	1	30	8	6			
---	9	1	30	8	3			
---	1							
---	1							
---	1							
---	1							
---	1							
---	1							
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---	1							
	1							

USER INPUT WORKSHEET CONTINUED

Biomass Transport Costs			
	40' - live floor - 22GT		
Select a Chip Van Type			
	Inputs	Units	Notes
Capacity	22	GT	
Moisture Content	50%	Percentage	
Possible Daily Production	180.0	BDT	
Potential Daily Production Rate	22.5	BDT/hr	
Loads Per Day	16	Loads	
Estimated Chip Van Demand	5	Vans	
Number of Vans with 1 Load per Day	0	Vans	
Number of Vans with 2 Loads per Day	0	Vans	
Number of Vans with 3 Loads per Day	4	Vans	Paid Hourly
Number of Vans with 4 Loads per Day	1	Vans	Paid an All-Day Fixed Fee
Actual Daily Transportation	176	BDT	

USER INPUT WORKSHEET CONTINUED

Transportation Estimate - Chip Van Transport			
	One-Way Distance (miles)	Average Speed (mph)	Notes
Highway	0	65	
Non-Highway Roads, Paved	20	40	
Unpaved Roads	5	20	
	Input	Units	Notes
Chip Van Transportation Cost	85	$/hour	
Biomass Loading Time	0.50	hours	
Biomass Unloading Time	0.50	hours	
Chip Van Fuel Economy	5.0	mpg	
Total Round Trip Time	2.5	hrs	

Project Overview			
	Input	Units	Notes
Current On Highway Local Retail Diesel Price	$3.90	$/gal	
Assumed On Highway Local Retail Diesel Price	$3.90	$/gal	
Project Overage	15%	Percentage	
Project Length	5	days	

RESULTS WORKSHEET

This Results Sheet highlights some of the important factors for an economic analysis of biomass feedstock availability. All of the cells in this sheet are calculated and no user input is required. To change the results, please return to the User Input Sheet or the Assumptions Sheet.

Result Summary		
Net Recoverable Biomass Volume	450	BDT
Mobilization Cost	1.37	$/BDT
Biomass Processing	16.53	$/BDT
SUBTOTAL	**17.90**	**$/BDT**
Transport Cost	18.35	$/BDT
Diesel Surcharge Adjustment	0.00	$/BDT
TOTAL COST	**36.26**	**$/BDT**
Project Time	5	days

Equipment Mobilization and Production Rates						
Equipment Type	Mobilization Cost ($)	Mobilization Cost ($/BDT)	Equipment Rates ($/hr)	Equipment Rates ($/BDT)	Total Cost ($/BDT)	Notes
Horizontal Grinder	308.10	0.68	350.00	11.93	12.62	
Loader/Shovel/Excavator	308.10	0.68	125.00	4.26	4.95	
Crew Vehicle	0.00	0.00	20.00	0.34	0.34	
---	---	---	---	---	---	
Totals	**616.20**	**1.37**	**495.00**	**16.53**	**17.90**	

Chip Van Cost			
Chip Van Type	Hauling Cost ($)	Hauling Cost ($/BDT)	Notes
40' - live floor - 22GT	3230	18.35	

QIN Biomass Fuel Volume and Pricing Model User Manual

"Assumptions" Worksheet"

This sheet shows primary major assumptions used in the model. The narrative at the top indicates cells within the Tables that are subject to change by the user, as well as data included in equipment costs.

Table A

Table A displays information regarding Grinder or Chipper equipment options. This table is limited to 3 rows/entries. There are three columns: Equipment Type, Equipment Rates ($/Hour) and Mobilization.

- Equipment Type indicates the particular machine employed in woody biomass processing. The Equipment Type column accepts any text entry.
- Equipment Rates ($/Hour) indicates the estimated hourly rate used for machine operation. The Equipment Rate column requires a number entry.
- Mobilization indicates whether the machine must be transported in by low bed (Yes). The Mobilization column accepts any text entry; however, any entry other than "Yes" will be read as "No".

Increasing the number of entries would require code changes and name management changes within Excel.

Table B

Table B displays information regarding all other equipment options that may be necessary for woody biomass processing operations. This table is limited to 11 rows/entries. There are three columns: Equipment Type, Equipment Rates ($/Hour) and Mobilization.

- Equipment Type indicates the particular piece of equipment employed in woody biomass processing. The Equipment Type column accepts any text entry.
- Equipment Rates ($/Hour) indicates the estimated hourly rate used for machine operation. The Equipment Rate column requires a number entry.
- Mobilization indicates whether the machine must be transported in by low bed (Yes). The Mobilization column accepts any text entry; however, any entry other than "Yes" will be read as "No".

Increasing the number of entries would require code changes and name management changes within Excel.

Table C

Table C displays information regarding Chip Van equipment options that may be necessary for woody biomass transport operations. This table is limited to 11 rows/entries. Increasing the number of entries would require code changes and name management changes within Excel. The Chip Van Size column accepts any text entry, though the entry should be a number. The Van Type column accepts any text entry. The GT Capacity column accepts any numerical entry. Note GT means Green Tons.

Table D

Table D displays information regarding the average "on highway" diesel price for any given biomass processing project. It would be used to adjust biomass delivery prices using a diesel surcharge for short-term increases in price, for example if diesel prices surged at least $.50 per gallon during the project period. It is not intended for use to provide a surcharge except for specific contracts/projects. Long-term changes in diesel prices would be reflected in changes to equipment hourly rates.

“User Input Sheet” Worksheet

This tab records all of the user input data. Additionally, the top two rows display a summary of key information in the results tab so that the user may be able to see how changes to the user inputs affect the end price.

Table A

Table A allows the user to input data to calculate an estimate of the available biomass. There are two biomass estimate options: 1) Timber Harvest Estimate and 2) Pile Estimate. Select by placing the mouse over either and clicking. The non-selected option area will gray out, leaving the selected option available for inputs. The Timber Harvest Estimate develops and estimate of biomass volume predicated upon unit harvest volume. The Pile Estimate allows the user to input estimated volume of biomass from slash pile measurements.

The Timber Harvest Estimate inputs are as follows:

<u>Timber Harvest Volume</u> – Input the total volume of timber harvested during a timber harvest operation in units of thousand board feet (MBF).
<u>Biomass Recovery Factor</u> – Input the mass (in BDT) of biomass recovered per thousand board feet removed. QIN should be able to refine this metric as biomass recovery occurs over time. The default values should be between .5 and 1.0 BDT per MBF.
<u>Moisture Content</u> – Input the moisture in the wood as a percentage of total mass. This value is not used when calculating the net biomass recoverable, but will be used in later calculations. The year-round average should be approximately 50%, with variations depending upon weather and how long slash has cured.
<u>Percent Unit Accessible</u> – Input an estimate of the percent of the total forest operation unit that is technically and economically accessible to biomass processing and transport equipment.
<u>Percent Unit Tops or Whole Tree Yarded</u> – Input whether tree tops or whole trees are yarded during harvest operation.
<u>Pulp Logs Removed</u> – Input whether pulp logs were merchandized and marketed from the harvest unit. This cell accepts Yes or No from a drop down menu.
<u>Chunkwood Removed</u>- Input whether Chunkwood was gleaned from existing slash material prior to conducting biomass processing operation. This cell accepts Yes or No from a drop down menu. Chunkwood is defined as woody material of sufficient size to be run through a debarker and processed as clean chips.

The Pile Estimate inputs are as follows:

Pile Input – Input the volume of material in the slash piles generated from pile measurements in Green Tons.
Moisture Content – Input the moisture in the wood as a percentage of total mass. The year-round average should be approximately 50%, with variations depending upon weather and how long slash has cured.

Table B

Table B allows the user to input data to calculate an estimated trip time and cost for transporting equipment to the site. In this model, the equipment is transported to and from the site only once, at the beginning and end of the project.

Inputs are:

Highway Information – The highway category allows the user to have two distinct speed categories for paved roadways. The highway category should represent the faster speeds of these two options, such as Highway 101. Note that the distances are one-way distances and that the average speed cannot be zero. This model only accepts numerical inputs.
Non-Highway Roads, Paved – The non-highway roads, paved category allows the user to have two distinct speed categories for paved roadways. The non-highway roads, paved category should represent the slower speeds of these two options, such as county or local roads. Note that the distances are one-way distances and that the average speed cannot be zero. This model only accepts numerical inputs.
Unpaved Roads – The unpaved roads category allows the user to define average speed and distances for travel along unpaved roads, such as those classed as forest roads. Note that the distances are one-way distances and that the average speed cannot be zero. This model only accepts numerical inputs.
Lowbed Transportation Cost – The lowbed transportation cost allows the user to define the hourly rate (in units of $/hr) for lowbed operations. This data input is not linked to any lowbed information previously defined in the Assumptions Tab, which allows the user to define other equipment instead of lowbeds, and different lowbed rates for equipment mobilization.
Equipment Loading Time – Equipment loading time represents the amount of time (in hours) to load a lowbed with the necessary equipment.
Equipment Unloading Time – Equipment unloading time represents the amount of time (in hours) to unload a lowbed with the necessary equipment.
Total Round Trip Time – This cell is calculated by the model based on the inputs previously provided.

Table C

Table C details all the equipment used in the biomass collection operation except the chip van. This should include any equipment that is used daily. The table is displayed in two sections: 1) Grinder or Chipper, and 2) Other Equipment. The Grinder or Chipper is noted separately because the productivity of this piece of equipment dictates the available daily production. The separation allows for this data to be easily retrieved by other cells when necessary for calculations. Note that all five columns must have inputs for the model to accept the equipment.

The columns are as follows:

Select Equipment from the Drop Down List – This column allows the user to select the type of equipment that will be used in the operation. These lists are populated from the inputs in Table A and Table B the Assumptions tab. Note that the biomass processing equipment is separate from the other equipment, and selection is limited to Tub Grinder, Horizontal Grinder or Horizontal Chipper. The other drop list allows the user to select the other equipment used to conduct the biomass recovery and processing operation.
Quantity – This column allows the user to specify the number of a particular unit that will be used. This column only accepts numerical inputs.
Equipment Production – This column allows the user to define the productivity of the equipment when operating at full capacity in BDT per hour per unit or piece of equipment. This column only accepts numerical inputs.
Scheduled Hours – This column allows the user to define the number of hours scheduled per day for the equipment to run. This number dictates the pay for the equipment. This column only accepts numerical inputs.
Productive Hours – This column allows the user to define the number of hours the equipment is actually running at full capacity each day. This number must be less than the scheduled hours. The productive hours dictate the daily production from the equipment. The productive hours are only utilized in for calculations for the Grinder or Chipper; however they are important when considering how to effectively minimize costs and redundancy during an operation. Note the input will not affect the cost. This column only accepts numerical inputs.
Utilization Rate – This column is calculated by dividing the productive hours by the scheduled hours to indicate the percentage of time that the unit is paid for where it is actually running at full capacity.
Adjusted Production – This column adjusts the equipment production to indicate the average hourly production based on uniformly distributed downtime as indicated by the productive hours.

Table D

Table D illustrates to the user how the transportation costs are calculated. The only input is a dropdown list for the user to select the type of chip van used. The dropdown list is populated by Table C on the Assumptions Tab.

The outputs for table D are as follows:

Capacity – This number is extracted from the data given for the selected chip van.
Moisture Content – This number is imported from the Timber Harvest or Pile estimate data and is used to determine the biomass volume for the selected chip van type.
Possible Daily Production – This number is calculated from the inputs for the Grinder or Chipper.
Potential Daily Production Rate – This number is imported from the Grinder or Chipper data.
Loads per Day – This number is calculated to show the number of full loads that can be hauled in a day given the possible daily production.
Estimated Chip Van Demand – This number estimates the minimum number of chip vans that would be necessary to satisfy the number of loads per day given the system constraints.
Number of Vans – These numbers are calculated based on the grinder production rates, the round trip times, the chip van loading constraints. These numbers represent one of many possible chip van schedules that would minimize the number of chip vans required based upon turn-around time. For any van that has a total daily operational time under 8 hours, the cost is calculated hourly; over 8 hours of operation and the cost is calculated as a daily fixed rate for a full day (8 hours).
Actual Daily Transportation – This number represents the actual amount of biomass delivered over the course of the day.

Table E

Table E allows the user to input data to calculate an estimated trip time for chip van transportation.

Inputs are:

Highway – The highway category allows the user to have two distinct speed categories for paved roadways. The highway category should represent the faster speeds of these two options, such as Highway 101. Note that the distances are one-way distances and that the average speed cannot be zero. This model only accepts numerical inputs.

Non-Highway Roads, Paved – The non-highway roads, paved category allows the user to have two distinct speed categories for paved roadways. The non-highway roads, paved category should represent the slower speeds of these two options, such as county or local roads. Note that the distances are one-way distances and that the average speed cannot be zero. This model only accepts numerical inputs.

Unpaved Roads – The unpaved roads category allows the user to define average speed and distances for travel along unpaved roads, such as forest roads. Note that the distances are one-way distances and that the average speed cannot be zero. This model only accepts numerical inputs.

Chip Van Transportation Cost – The chip van transportation cost allows the user to define the hourly rate (in units of $/hr) for chip van operators.

Equipment Loading Time – Equipment loading time represents the amount of time (in hours) to load the chip van to capacity.

Equipment Unloading Time – Equipment unloading time represents the amount of time (in hours) to unload the chip van.

Chip Van Fuel Economy – The chip van fuel economy input allows the user to define the fuel economy in miles per gallon for the chip van selection. This number is used to calculate the price changes due to a jump in diesel prices.

Total Round Trip Time – This cell is calculated by the model based on the inputs previously provided.

Table F

Table F allows the user to input additional project data with regard to on-highway diesel prices and project duration.

Current Diesel Price – This input allows the user to see the effects of a price change in diesel that is not reflected in the hourly price of the equipment. This data is used to calculate a diesel surcharge cost when short-term diesel prices increase significantly during the course of a specific project. Long-term changes in diesel prices will be reflected in changes in equipment hourly rates.

Assumed Diesel Price – This cell is retrieved directly from Table D in the Assumptions Tab

Project Overage – This value allows the user to introduce a factor of safety, production or downtime for the project timeline. This number is used when calculating the estimated project length.

Project Length – The project length is calculated from the production data and the harvest estimate data provided.

“Results” Worksheet

The Results tab includes all of the key outputs from the model. There are no user inputs on this tab.

Table A

Table A summarizes the important project costs in $ per BDT calculated from data provided in the User Input Worksheet.

Table B

Table B details the costs of utilizing various equipment selected for use in the biomass recovery and processing operation, and provides a break-down of the costs associated with the equipment. Note these values represent the total cost for all of the equipment of a given type (i.e., multiple pieces of the same equipment); this data does not represent cost per equipment piece.

Table C

Table C details the cost of the transporting and delivering biomass. Note these values represent the cost for all of the equipment of a given type (i.e., multiple chip vans); this data does not represent cost per chip van.

APPENDIX D JOURNAL OF AIR AND WASTE MANAGEMENT ASSOCIATION ARTICLE

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Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning

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ABSTRACT

Woody biomass waste is generated throughout California from forest management, hazardous fuel reduction, and agricultural operations. Open pile burning in the vicinity of generation is frequently the only economic disposal option. A framework is developed to quantify air emissions reductions for projects that alternatively utilize biomass waste as fuel for energy production. A demonstration project was conducted involving the grinding and 97-km one-way transport of 6096 bone-dry metric tons (BDT) of mixed conifer forest slash in the Sierra Nevada foothills for use as fuel in a biomass power cogeneration facility. Compared with the traditional open pile burning method of disposal for the forest harvest slash, utilization of the slash for fuel reduced particulate matter (PM) emissions by 98% (6 kg PM/BDT biomass), nitrogen oxides (NO_x) by 54% (1.6 kg NO_x/BDT), nonmethane volatile organics (NMOCs) by 99% (4.7 kg NMOCs/BDT), carbon monoxide (CO) by 97% (58 kg CO/BDT), and carbon dioxide equivalents (CO_2e) by 17% (0.38 t CO_2e/BDT). Emission contributions from biomass processing and transport operations are negligible. CO_2e benefits are dependent on the emission characteristics of the displaced marginal electricity supply. Monetization of emissions reductions will assist with fuel sourcing activities and the conduct of biomass energy projects.

INTRODUCTION

Woody biomass waste material is generated as a byproduct throughout Placer County portions of the Sacramento Valley, foothills, and Sierra Nevada mountains from forest management projects, defensible space clearing, tree trimming, construction/demolition activities, and agricultural operations.

Forest management projects that produce woody biomass byproducts (tree stems, tops, limbs and branches, and brush) include fuel hazard reduction, forest health and productivity improvement, and traditional commercial harvest. These projects take place on private land and lands managed by various public agencies including the U.S. Forest Service (USFS), Bureau of Land Management, and state/federal parks. Forest fuel hazard reduction activities involving selective, targeted thinning treatments are implemented to lessen wildfire severity and improve forest-fire resiliency through reducing hazardous fuel accumulations resulting from a century of successful wildfire suppression efforts. Commercial timber harvests include thinning to improve health and productivity, and intensive management to optimize the yield of merchantable material for lumber production.

Defensible space clearings and fuel breaks in an expanding wildland urban interface area, including residential and commercial structures, produce woody biomass that typically includes deciduous and coniferous trees and brush.

Agricultural operations such as fruit and nut orchards and grape vineyards are a source of biomass wastes from annual pruning and periodic removal and replacement with more productive varieties or growing stock.

Open burning (in piles or broadcast burning) near the site of generation is the usual method of disposal for a significant quantity of the excess woody waste biomass throughout much of the western United States. A forest slash pile burn in the Lake Tahoe Basin is shown in Figure 1. The cost to collect, process, and transport biomass waste is often higher than its value for fuel or wood products because of the distance of the forest treatment activity location from the end user (e.g., mill, biomass energy facility), lack of infrastructure, and/or economics of biomass energy compared with fossil fuel generation. This limits the feasibility of using biomass waste for energy production although such use has significant environmental benefits.

IMPLICATIONS

Economic considerations frequently dictate the disposal of woody biomass wastes by open burning. The alternative use for energy provides significant reduction in criteria air pollutant and greenhouse emissions. Valuing these reductions will improve the economic viability and increase the use of biomass for energy as well as assist with forest and agricultural management objectives.

Figure 1. Open pile burn of forest fuel treatment woody biomass in Lake Tahoe Basin.

The Placer County Air Pollution Control District (PCAPCD), with responsibility for managing air quality in Placer County, shares regulatory authority over open burning with local fire agencies. Open burning is problematic because of the limited time of year it can be conducted, subsequent monitoring of smoldering piles for days after they are lit, and the production of significant quantities of air pollutant emissions and esthetically unpleasing residuals (blackened logs and woody debris). The PCAPCD expends significant resources reviewing smoke management plans, issuing burn permits, inspecting burn piles, and responding to complaints from smoke.

PCAPCD[1,2] and others[3,4] report that the utilization of woody biomass waste for energy as an alternative to open burning can provide significant air emissions mitigation for criteria pollutants, air toxics, and greenhouse gases, along with energy benefits through production of renewable energy in a well-controlled conversion process. To quantitatively value these benefits, PCAPCD is developing an emission reduction accounting framework and has sponsored several biomass waste-for-energy field operations to evaluate alternatives to minimize open burning.

EMISSION REDUCTION ACCOUNTING FRAMEWORK

The emission reduction framework is intended to provide a basis for financial support for the utilization of biomass wastes for energy in which the biomass waste under "baseline, business as usual" conditions would have been open-burned. This requires an evaluation of the economics of the biomass management alternatives and institutional and regional practices to demonstrate that the biomass waste would be open-burned without the additional financial contributions from a biomass project proponent. Biomass must also be shown to be a byproduct of forest or agricultural harvest projects that meet local, state, and federal environmental regulations, including the National Environmental Policy Act, the California Environmental Quality Act, and/or Best Management Practices. The biomass must also be demonstrated to be excessive to ecosystem needs.

Net emission reductions are considered to be the difference between the biomass energy project and the open burning baseline. As shown in Figure 2, the biomass project boundary includes processing (loading and chipping), transport, and the energy conversion plant. The baseline considers biomass open burning and the marginal generation of energy that was displaced by the biomass project. Table 1 details the project activities and data requirements for emissions reduction determinations that are real, permanent, quantifiable, verifiable, and enforceable.

Emissions from the forest management projects and agricultural operations that generate the excess biomass waste (e.g., chain saws and yarders) are not considered in the accounting framework because biomass removal is required for management purposes and will occur regardless of which biomass disposal option is pursued. Biomass waste that falls under the framework must have economic value that is less than the cost to process and transport (it must be a disposal burden). The biomass removal operations must be required for reasons (e.g., fire hazard reduction, forest management, timber production, or food production) that are unrelated to any potential biomass value. Furthermore, emission contributions from the biomass removal operations are minor compared with processing, transport, or open burning.[3,4]

Emissions from operations to process and transport fossil fuels, which are used in the baseline to provide equivalent energy and in the biomass project to facilitate wood chip transport and biomass processing/loading equipment, are not considered because of the difficulty of accurately defining their energy usage and emission characteristics.

It is anticipated that reductions resulting from biomass utilization projects may be banked or sold for air emissions and/or greenhouse gas mitigation obligations.

DEMONSTRATION PROJECT

PCAPCD and the County of Placer Biomass Program teamed with USFS, Sierra Pacific Industries (SPI), and the Sierra Nevada Conservancy to sponsor an on-the-ground biomass waste-for-energy demonstration project. The project targeted woody biomass waste piles that were originally generated from two USFS fuel reduction stewardship contracts implemented in 2007 on the Tahoe National Forest, American River Ranger District, which is located above Foresthill, CA. The stewardship contracts involved the thinning treatment of over 1215 ha of mixed conifer and ponderosa pine stands with 500-1000 trees/ha (preharvest). The thinning prescription had a target of

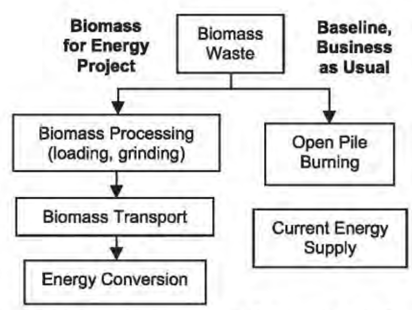

Figure 2. Biomass-for-energy project emission reduction procedure.

Table 1. Project data and monitoring.

Parameter	Method, Frequency
Biomass weight delivered to energy conversion facility	Transport vehicle weight scale, each separate delivery
Biomass moisture	Representative sample, when biomass source changes
Biomass heating value	Representative sample, when biomass source changes
Transport vehicle miles traveled and gas mileage	Vehicle odometer, fuel dispensing
Processing equipment diesel engine operating hours and fuel usage	Engine hour meter, fuel dispensing
Energy production efficiency of energy conversion facility	Fuel input and useful energy output
Emission factors for open pile burning	Literature review
Emission factors for fossil fuel combustion engines	Engine manufacturer, literature
Emission factor for grinding	Literature review
Emission factor for transport over unpaved roads	Literature review
Emission factors for biomass energy conversion facility	Source testing, annual
Emission factors for displaced energy	Marginal energy supply analysis, source testing

180–250 trees/ha at 7.6-m spacing through selected removal of trees 10–51 cm in diameter at breast height (DBH). Removed biomass that was greater than 15 cm DBH and greater than 3.1 m long was transported to a sawmill for processing into lumber products. The stewardship contracts called for unmerchantable slash to be piled at the site for later open burning, the traditional method of disposal.

For the demonstration project, a forest products contractor, Brushbusters, Inc., was retained to process and transport the woody biomass waste piles for use as fuel in a cogeneration facility located at a SPI lumber mill in Lincoln, CA. At each landing slash pile location, excavators were used to transfer the piles into a horizontal grinder. Wood chips from the grinder were conveyed directly into chip vans and transported to the SPI Lincoln mill, a 97-km one-way trip. Equipment and engines used for the chipping and transport operations are described in Table 2.

The SPI Lincoln sawmill facility includes a wood-fired boiler that produces steam for use in lumber drying kilns and a steam turbine that produces up to 18 MW of electricity. The boiler is a McBurney stoker grate design with a firing rate capacity of 88 MW that produces 63,560 kg of steam at 90 bar and 510 °C. It is fueled by biomass wastes including lumber mill wood wastes generated on-site (primarily sawdust), agricultural wastes including nut shells and orchard removals and prunings, wood waste from timber operations, and urban wood waste (tree trimmings and construction debris). The boiler utilizes selective noncatalytic reduction for control of nitrogen oxides (NO_x), multiclones, and a three-field electrostatic precipitator for particulate matter (PM) control. The net boiler heat rate is 16.8 MJ of heat input per kWh electric net, a net efficiency of 22%.

Table 2. Equipment and engines for biomass processing and transport.

Equipment	Vendor, Model, Year	Engine, Model, Horsepower
Horizontal grinder	Bandit Beast, model 3680, 2008	Caterpillar C18, Tier III, 522 kW
Excavator	Linkbelt, model 290, 2003	Isuzu CC-6BG1TC, 132 kW
Excavator	Linkbelt, model 135, 2003	Isuzu BB-4BG1T, 66 kW
Chip van	Kenworth, 1997	Cummins N14, 324 kW
Chip van	Kenworth, 2006	Caterpillar C13, 298 kW

During the period of April 14, 2008 through December 12, 2008, on 86 separate work days, 6096 bone-dry metric tons (BDT) (9537 green tons [GT]) of forest slash were collected, processed, and transported. A total of 444 separate chip vanloads were delivered to the SPI boiler, with each delivery averaging 13.7 BDT (21.5 GT).

The biomass processing machines (a grinder and two excavators) each worked a total of 265 hr and produced biomass fuel at the rate of 36.3 GT per hour of equipment operation. Diesel engine fuel consumption for the grinder and two excavators averaged 2.92 and 0.79 L/GT, respectively. This is comparable with the grinder fuel usage of 2.1 and 3.1 L/GT reported in other studies.[3,4] Chip transport truck/trailer diesel fuel usage averaged 1.9 km/L over the 193-km round trip (4.6 L/GT), also comparable to other studies.[3,4]

Biomass fuel delivered to the boiler had an average heating value of 20.9 MJ/kg, a moisture content of 36.1%, and an ash content of 2% dry weight. The boiler produced 7710 MWh of electricity utilizing biomass fuel from this project.

The biomass project significantly reduced the utilization of fossil fuels. The project required 511 MJ of diesel/BDT, but it displaced the need for 9806 MJ of natural gas/BDT for electricity generated by the biomass-fired cogeneration facility. Energy benefits would be greater if the fossil fuel energy required to collect, refine, and deliver fossil fuel to market (with added fossil fuel energy penalty on the order of 20%) was considered.[3]

Table 3 shows the emission factors used to calculate project and baseline operations, including NO_x, PM, carbon monoxide (CO), nonmethane volatile organics (NMOCs), methane (CH_4), and carbon dioxide (CO_2). Open pile burning factors considering numerous laboratory-, pilot-, and full-scale studies on conifer biomass are compiled in Table 4.[5–23] The burn pile emission factor was used with a burn pile consumption efficiency rate of 95%. Diesel engine combustion, chipping, and unpaved road travel emission factors are from the California Air Resources Board and the U.S. Environmental Protection Agency (EPA).[24–28] Biomass boiler factors are from annual

Table 3. Emission factors for project and baseline operations.

Process/Reference	Units	NO_x	PM	NMOC	CO	CO_2	CH_4
Open pile burning[5–20]	g/dry kg wood	3	6.5	5	63	1833	3
Chip van engine[24]	g/km traveled	10.6	0.25	0.31	25	1381	0.6
Chip van[25]	g/km unpaved road	–	300	–	–	–	–
Grinder engine[26]	g/kWh	3.1	0.18	0.16	4.0	530[b]	0.32
Excavator engine[26]	g/kWh	5.6	0.17	0.25	5.4	350[b]	0.51
Excavator engine[26]	g/kWh	6.4	0.26	0.31	6.7	370[b]	0.62
Grinder[27]	g/green kg wood	–	0.05	–	–	–	–
Biomass boiler[22]	g/GJ	52	7.7	1.7	73	88,000	4
Natural gas combined cycle[23]	Kg/MWh	0.016	0.011	0.002	0.005	384	–
California in-state electricity production[a,28]	Kg/MWh	0.08	0.025	0.01	0.13	250	–

Notes: [a]Shown for comparison purposes; [b]Determined from engine diesel fuel usage, operating hours, and rated power output.

manual method stack sampling test programs and continuous emission monitors that are required by PCAPCD to demonstrate compliance with permit limits.[22] Electricity production factors are from the displacement of marginal power from a local utility natural gas combined cycle 120-MW plant that uses selective catalytic reduction and oxidation catalysts for NO_x and CO control.[23] For comparison, overall California state electricity generation emissions factors are also shown.[28]

Table 5 compares biomass project emissions with baseline (open pile burning) emissions. The project reduced PM emissions by 98% (6 kg PM/BDT biomass), NO_x emissions by 54% (1.6 kg NO_x/BDT), NMOC emissions by 99% (4.7 kg NMOCs/BDT), CO emissions by 97% (58 kg CO/BDT), and CO_2 equivalent (CO_2e; determined as $CO_2 + 21 \times CH_4$) emissions by 17% (0.38 t CO_2e/BDT).

The cost to process and transport the piles to the SPI cogeneration facility averaged $64.40/BDT, including $33/BDT to process and $31/BDT to transport the piles. The competitive market value at the time of the project for biomass sourced from timber harvest residual in the central Sierra Nevada region was approximately $33/BDT. The cost to dispose of the biomass wastes at the site of generation with open pile burning is relatively small. Thus, the demonstration program operated with a cost deficit of $31.30/BDT biomass processed.

For the demonstration project to be economically viable, the cost to process and deliver the biomass must be reduced, the price paid at the cogeneration facility must be increased, and/or emission reduction credits must be sold. To break even, emission reduction credits would need to be valued for CO_2e at $83/t CO_2e, NO_x at

Table 4. Emission factors for open pile burning of woody biomass.

Source, Reference, Test Conditions, Material Type	Material Type	Emission Factor (g/kg dry biomass burned) PM	CO	CH_4	NMOC	NO_x
EPA AP-42,[18] conifer logging slash, piled	Flaming	4	28	1.0	–	–
	Smoldering	7	116	8.5	–	–
	Fire	4	37	1.8	–	–
EPA AP-42,[17] pile burn	Unspecified	14	116	4.7	15	–
	Fir, cedar, hemlock	3.4	75	1	3.4	–
	Ponderosa pine	10	164	2.9	9	–
Ward et al.,[19] Hardy,[10] consume model, 90% consumption efficiency	Dozer piled	6	77	6	4	–
	Crane piled	13	93	11	8	–
	Consume 90% consumption efficiency	9	80	3.8	3.1	–
Jenkins et al.,[12] wind tunnel simulator	Almond	5	53	1.3	10	4
	Douglas fir	7	56	1.5	6	2
	Ponderosa pine	6	43	0.9	4.4	3
	Walnut tree	5	71	2.0	7	5
Lutes and Karher,[14] pilot, land clearing piles		7–22	19–29	–	4–16[a]	0.2–2
Andreae and Merlet,[5] literature compilation		5–17	81–100	–	–	–
Janhall et al.,[11] literature compilation, forest residues		8	–	–	–	–
Chen et al.,[7] laboratory	Ponderosa pine wood	4	17	–	0.5[a]	0.8
	Ponderosa pine needles	3.3	32	–	3.5[a]	4.1
Freeborn et al.,[8] laboratory, pine, fir, aspen		7	50	–	–	4
McMeeking et al.,[16] laboratory, pine, fir		–	90	3.7	5	2.2
Yokelson et al.,[20] pilot	Broadcast	8	–	–	2[a]	3
	Slash	4	–	–	2[a]	2
	Crowns	–	–	–	4[a]	3

Notes: [a]Total hydrocarbons.

Table 5. Emissions comparison: open pile burning vs. biomass energy.

Operation	Air Emissions (t)						
	NO_x	PM	NMOC	CO	CO_2	CH_4	CO_2e^a
Baseline, open pile burning							
Open pile burning	17.37	37.65	28.96	362	10,618	17.37	10,983
Displaced power from grid	0.47	0.28	0.06	1	2,733		2,733
Total	17.84	37.93	29.02	363	13,352	17.37	13,717
Biomass project							
Boiler	6.58	0.98	0.22	9	11,178	0.55	11,189
Process and transport							
Grinding	0.43	0.52	0.02	1	73	0.04	74
Loading	0.31	0.01	0.01	0	19	0.03	19
Chip van transport	0.91	0.02	0.03	2	118	0.05	119
Total	8.23	1.53	0.28	12	11,388	0.70	11,402
Emissions reductions	9.62	36.39	28.74	350	1,965	16.7	2,315
Percent reduction	54%	96%	99%	97%	15%	96%	17%

Notes: [a]CO_2e determined as $CO_2 + 21 \times CH_4$.

\$19,570/t NO_x, or at a lower price if a combination of pollutant credits is sold. Biomass market fuel prices are trending upward partly because of an increased demand for renewable energy (resulting from the California Renewable Portfolio Standard).

Opportunities were identified to significantly reduce future biomass waste processing costs through maximizing equipment productive work time (minimizing equipment downtime and mobilization) by careful formation of piles, creation of larger piles, and efficient scheduling and coordination of truck transport and grinding equipment. In particular, the grinder (the most expensive cost center) was frequently idle while waiting for the arrival of chip truck transport. Cost reductions can be achieved through operating the grinder closer to full time by using additional chip trucks or grinding into piles that are subsequently loaded into chip trucks at a later time with less expensive equipment such as front-end loaders.

The largest source of uncertainty in the emissions determinations is from the biomass open pile burning emissions factor. Open pile burn emission factors vary depending on woody biomass chemical composition (moisture, ash), physical characteristics (pile packing size and arrangement, biomass particle size), and atmospheric conditions (temperature, humidity, wind speed). Variability in the biomass open pile burn emissions factor will impact the magnitude of the emission reductions, but it will not alter the conclusion that emissions from the biomass energy project are lower compared with open pile burning. Variability for emissions from the diesel engines, biomass boiler, and displaced electricity grid operations are not significant to the project results because emissions factors from the processes are well established, process operating rates are accurately measured and monitored, the processes are inherently steady, and contributions from these sources are generally much smaller than those from open pile burning.

The demonstration project results are readily applicable to a very broad range of potential forest sourced biomass projects throughout the West and the entire United States. The biomass energy recovery boiler design, operation, and performance used for the demonstration project are representative of existing plants that are in commercial service throughout the United States. Emission contributions from biomass processing and transport are very small in comparison with traditional open pile burning. Thus variations in grinding efficiency, transportation distance, and engine emission characteristics will have very little impact on emission reductions. Transportation distance has a significant impact on the economic viability of biomass energy projects, adding approximately \$0.13/BDT per additional kilometer traveled, but it has very little impact on emission benefits.

CO_2 benefits are strongly dependent on the CO_2 emissions profile from the displaced marginal electricity source. Reductions will be much greater than achieved in the demonstration project for biomass projects in areas where coal firing is prevalent, whereas benefits will be minimal in areas where production is from lower CO_2-emitting sources such as hydroelectric and/or nuclear sources.

NO_x benefits are somewhat dependent on biomass boiler performance. NO_x reductions will be significantly greater than in the demonstration program for low NO_x-emitting systems including emerging energy conversion technologies such as gasification, pyrolysis, and fuel cells and recently constructed or modified biomass boilers that use selective catalytic reduction.

CONCLUSIONS

A framework is developed to quantify air emission reductions for projects that utilize woody biomass waste as fuel for energy production as an alternative to open burning. A demonstration project was conducted involving the grinding and 97-km transport of forest slash in the Sierra Nevada foothills for use in a biomass-fired cogeneration boiler. Significant air emission benefits were obtained: PM emissions were reduced by 98% (6 kg PM/BDT), NO_x emissions by 54% (1.6 kg NO_x/BDT), NMOC emissions by 99% (4.7 kg NMOC/BDT), CO emissions by 97% (58 kg CO/BDT), and CO_2e emissions by 17% (0.38 t CO_2e/BDT).

PM, NO_x, CO, and volatile organic emission reductions result from the utilization of biomass wastes in an energy conversion process that provides efficient combustion and uses add-on control methods for PM and NO_x emissions compared with the inefficient and uncontrolled disposal of biomass wastes using traditional open burning techniques. CO_2e benefits result from the production of renewable energy that displaces marginal supply and elimination of CH_4 emissions from open burning.

Biomass processing (grinding) and transport operations have a significant cost burden on the biomass energy project but a negligible contribution to air emissions. CO_2e benefits are strongly dependent on the CO_2e emission characteristics of the displaced marginal energy generation; benefits will be much greater for projects in regions where coal firing is predominant. Recognition of the value of emission benefits through sale of emission reduction credits will improve the financial performance of biomass power generation facilities and allow them to access more forest- and agricultural-sourced biomass waste fuel.

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APPENDIX E EQUIPMENT LIST FOR DENSIFIED FUEL LOGS

DENSIFIED LOG PLANT EQUIPMENT AND COST			
EQUIPMENT	**PURCHASED & INSTALLED NEW**	**PURCHASED & INSTALLED USED**	**TOTALS**
Front end loader	$75,000		$75,000
Fork lift	$20,000		$20,000
Feeder	$65,000		$65,000
Burner/Dryer		$1,501,500	$1,501,500
Log machine		$401,000	$401,000
Dryer controls	$50,000		$50,000
Multiclones	$75,000		$75,000
Cyclones	$150,000		$150,000
Hammermill	$100,000		$100,000
Packaging Line	$100,000		$100,000
Baghouses	$150,000		$150,000
Conveyance	$150,000		$150,000
Air compressor	$10,000		$10,000
Airlocks	$30,000		$30,000
Surge bins	$50,000		$50,000
Electrical		$250,000	$250,000
Mechanical		$20,000	$20,000
Pneumatic		$200,000	$200,000
Engineering		$50,000	$50,000
Concrete/Steel		$75,000	$75,000
Freight	$10,000	$10,000	$20,000
SUBTOTAL	**$1,035,000**	**$2,507,500**	**$3,542,500**
Contingency 18%			$637,650
TOTAL	**$1,035,000**	**$2,507,500**	**$4,180,150**
Finished Product Target	10,000 tons		
Raw Material Moisture	50%		

APPENDIX F MESSERSMITH MAINTENANCE SCHEDULE AND OPERATOR TRAINING

MAINTENANCE ITEM	OCCURRENCE (ALL TIMES ARE IN MINUTES)				
	DAILY OR AS NEEDED	ONCE A WEEK	ONCE A MONTH	TWICE A YEAR	ONCE A YEAR
Daily visual inspection, including checking water level & belts for wear and making sure nothing is on the rails. Check for leaks, noise, vibration, unusual conditions, etc.	10				
Record boiler operating pressure/temperature, flue gas temperature, and makeup water usage.	5				
Rake ashes off grates.	10				
Remove ashes from boiler. ***We recommend at least twice a week.***		10			
Clean out from under the grates.				10	
Check boiler tubes and manually clean if needed.				10 to 60	
Clean ashes from smoke box, breeching, chimney.				15+	
Empty ash from the barrel under the dust collector.			15		
Grease induction fan and bearings			5		
Grease bearings at both ends of metering auger(s).					5
Grease stoker auger bearing(s).			5		
Grease traveling auger pillow-block bearing. (Note: the bearings on which the carriage rides are sealed and should not need greased.)			5		
Grease bearings of the idler sprocket for the travel.					5
Grease bearings on belt conveyor(s) & belt brush.			15		
Grease combustion door hinges.					5
Remove dust from boiler room surfaces.		10			
Lubricate motors as manufacturer recommended.					
Check the motor brushes for motor of the metering auger(s) (a DC motor). Replace as needed.					30
Lubricate chains with spray lube made for roller chains. Note: travel chains will not need oiled.			10		
Check for tightness of chains.			5		
Check for wear of sprockets & chains. Replace as needed.				5 to 30	
Check the tightness of the conveyor belts.			5		
Check for wear of the belt brush and/or wiper.			5		

MAINTENANCE ITEM	OCCURRENCE (ALL TIMES ARE IN MINUTES)				
	DAILY OR AS NEEDED	ONCE A WEEK	ONCE A MONTH	TWICE A YEAR	ONCE A YEAR
Maintain air compressor as manufacturer recommended.					
Clean fuel out from under belt/roundabout.		5			
Clean fireside surfaces and inspect refractory				60	
Check operating, limit, safety, and interlock controls			20		
Check belt drive (ID fan)			20		
Tighten all electrical terminals after locking out power.					15
TOTALS	**25**	**25**	**110**	**100 to 175**	**60**

Messersmith Manufacturing, Inc. Training List

The following items are covered in our operator training:

- Sensors & Switches:
  - Conveyor Sensor
  - Directional Switches
  - Deflector Switch
  - Metering Sensors
  - Metering Bin Cover Switch
  - Low Water Cut Off
  - High Temperature
- Motors:
  - Conveyor
  - Metering
  - Stoker
  - Under-fire & Over-fire Fans & Dampers
  - Bin Auger
  - Travel
  - Draft Fan
  - Air Compressor & Automatic Tube Cleaning System
- Augers:
  - Bin auger
  - Metering
  - Stoker
- Controls:
  - Main Computer (panel & all aspects)
  - VFD Drive (Draft Fan)
- Fire Safety:
  - Danfoss Valve
  - Sprinkler (Metering bin)
- Combustor:
  - Rake Down
  - Clean Out-Ash Removal
  - Door - Opening & Closing
  - Cold Start
- Miscellaneous:
  - Conveyor Adjustment & Alignment
  - Chip Screen & Chip Specs.

Chip Bin (Moving/Loading Chips)
Maintenance
Common Troubleshooting

We also explain how to brush the tubes of the boiler.