California Assessment of Wood Business Innovation Opportunities and Markets (CAWBIOM)

Phase I Report: Initial Screening of Potential Business Opportunities

Completed for:

The National Forest Foundation

THE BECK GROUP

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CALIFORNIA ASSESSMENT OF WOOD BUSINESS INNOVATION OPPORTUNITIES AND MARKETS (CAWBIOM)

PHASE 1 REPORT: INITIAL SCREENING OF POTENTIAL BUSINESS OPPORTUNITIES

PHASE 1 REPORT
JUNE 2015

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Acronyms Used In This Report

AB 32 – California Global Warming Solutions Act
APA – The Engineered Wood Association
ASTM – American Society for Testing and Materials
B&V – Black & Veatch
BBER – Bureau of Business & Economic Research
BSF – Billion Square Feet
BTU – British Thermal Unit
CARB – California Air Resources Board
CA ISO – California Independent System Operator
C – Celsius
CI – Carbon Intensity
CC – Contract Capacity
CEC – California Energy Commission
CEQA – California Environmental Quality Act
CHP – Combined Heat and Power
CNC – Carbon Nano Crystal
CNF – Carbon Nano Fiber
CPI – Consumer Price Index
CQ – Contract Quantity
CCS - Carbon Capture and Sequestration
CLT – Cross Laminated Timber
CSPC – Carlson Small Power Consultants
CPUC – California Public Utilities Commission
D/C – Demand to Capacity Ratio
BECK – The Beck Group
BDT – Bone Dry Tons
BLM – Bureau of Land Management
EBIT – Earnings before Interest Taxes
EBITDA – Earnings Bef. Int. Taxes Depreciation Amortization
EPA – Environmental Protection Agency
ERR – Eligible Renewable Resource
FEA – Forest Economic Advisors
FERC – Federal Energy Regulatory Commission
FGS – Fruit Growers Supply
FOB – Free On Board
GDP – Gross Domestic Product
GHG – Green House Gas
GT – Gas Turbine
IC – Internal Combustion
IOU – Investor Owned Utility
IP – Isoprenic Units
KD – Kiln Dry
KW – Kilowatt
KWH – Kilowatt Hour
LCFS – Low Carbon Fuel Standard
LVL – Laminated Veneer Lumber
LED – Large End Diameter
LEED – Leadership in Energy and Environmental Design
LHV – Lower Heating Value
LNG – Liquefied Natural Gas
LPG – Liquefied Propane Gas
LSL – Laminated Strand Lumber
MBF – One Thousand Board Feet
MC – Moisture Content
MDF – Medium Density Fiberboard
MMBF – One Million Board Feet
MB&G – Mason Bruce & Girard
MMBTU – Million British Thermal Units
MMSF – One Million Square Feet
MOE – Modulus Of Elasticity
MRC – Mill Residual Chip
MSF – One Thousand Square Feet
MSR – Machine Stress Rated
MT – Metric Ton
MW – Megawatt
MWH – Megawatt Hour
NIPF – Non-Industrial Private Forestland
NFF – National Forest Foundation
NMTC – New Market Tax Credit
NNI – National Nanotechnology Initiative
OEM – Original Equipment Manufacturer
OSB – Oriented Strand Board
OSL – Oriented Strand Lumber
PG&E – Pacific Gas & Electric
PPA – Power Purchase Agreement
PSL – Parallel Strand Lumber
PURPA – Public Utilities Regulatory Policy Act
QF – Qualifying Facility
ReMAT – Renewable Marketing Adjusting Tariff
RFP- Roseburg Forest Products
RPS- Renewable Portfolio Standard
S-DRY – Surface Dry
S-GRN – Surface Green
SB 1122 – Senate Bill 1122 (Bioenergy Feed In Tariff)
SCE – Southern California Edison
SDG&E – San Diego Gas & Electric
SED – Small End Diameter
SFM – Sustainable Forest Management
SPI – Sierra Pacific Industries
SRAC – Short Run Avoided Cost
TFM – Thermally Fused Melamine
UC – University of California
USDOE – United States Department of Energy
USFPL – United States Forest Products Lab
USFS – United States Forest Service
VOC – Volatile Organic Compound
WLC – Whole Log Chipping
WPC – Wood Plastic Composite

CHAPTER 1 – EXECUTIVE SUMMARY

1.1 INTRODUCTION

The National Forest Foundation issued a Request for Proposal to assess the current state of California's forest products industry, identify forest products business opportunities that will help the U.S. Forest Service increase the pace and scale of forest ecosystem restoration, identify gaps and weaknesses in policy, and prepare business plans with actionable items for the most promising business opportunities. The Beck Group (BECK), a Portland, Oregon based forest products planning and consulting firm, was selected to complete the project. BECK organized a project team with expertise in the disciplines of forest inventory and timber supply, forest products technology, and business feasibility and planning.

The project scope was divided into two phases. In the first phase, a comprehensive list of technologies for converting wood fiber into products was developed. The technologies judged to provide the most promise for being developed into viable businesses in the context of California's forest products industry were identified. The results of Phase I are summarized in this report. In the second phase, detailed feasibility assessment and business planning will be completed for the selected business opportunities and recommendations will be made about gaps and weaknesses in policy.

1.2 INTERIM REPORT – BRIEF SUMMARY

1.2.1 California's Forest Products Industry

California has nearly 17 million acres of timberland, which supports a forest products industry that utilizes sawlogs, veneer logs, small diameter trees, logging slash, and mill residues. Since the industry creates value from those forest-derived materials, forest landowners can cost-effectively carry out forest management activities to maintain and improve forest health, reduce wildfire risk, and realize a positive return from the sale of timber.

Sawmills are a foundational component of California's forest products industry because the high value created from lumber production drives the ability to cost-effectively manage forests. However, generally only about 50 percent of a log's volume is converted to lumber. Therefore, sawmills produce large volumes of mill residues in the form of chips, sawdust, shavings, and bark. In other regions of North America, sawmill residues provide as much as 25 to 30 percent of a mill's total revenue. This is not the case in California because secondary wood fiber users such as pulp and paper mills, composite panel users, and pellet plants are either largely gone, or never existed in the state. In addition, California's biomass heat and power plants, which are one of the few markets for mill residues, are quickly disappearing as their contracts to sell power to utilities are not being renewed. For these reasons, a focus of this study was identifying technologies that can utilize mill residues and thereby enhance the viability of California's sawmills.

According to the California Forest Foundation[1], forests in the Sierra Nevada historically held about 50 to 70 trees per acre. Today, publicly owned forests in the Sierra Nevada typically hold 300 to 500

[1] Protecting Communities and Saving Forests. Accessed at: http://www.calforestfoundation.org/pdf/Protecting+Communities+And+Savings+Forests.pdf

trees per acre. Today's overstocked forests are at high risk for insect and disease attack and wildfire. Restoring those forests to historic conditions is a goal of public agencies responsible for their management. Many of the trees in those overcrowded forests are relatively small diameter, which means utilizing them in a sawmill is generally not economical. Therefore, a second key study focus was identifying technologies that can utilize small diameter trees and that are of sufficient scale to have a meaningful impact on forest restoration efforts.

1.2.2 Top Technologies

Given those key objectives, the project team identified over 45 technologies for utilizing wood fiber. The team used criteria such as market attractiveness, scale of operation, and proven commercial viability to narrow the technology list to four that were judged to have the greatest potential for becoming viable forest products based businesses in California. They include:

- **Cross Laminated Timber (CLT)** – is a new to North America technology that uses lumber to make massive timber panels which are used in floor, wall, and roof systems in buildings up to 85 feet tall under current building codes. The largest CLT plants in the world consume about 50 million board feet of lumber annually. The key advantages of this technology are: it creates a new, relatively large market for lumber and the market for CLT is expected to be strong in California since structures made from it have been found to have strong seismic performance characteristics. The key challenge to this technology is how quickly the market will develop as broader use of CLT is adopted.

- **Oriented Strand Board (OSB)** – is a structural panel most commonly used as wall and roof sheathing material in residential construction. The key benefits of this technology are: it is large scale – a typical plant utilizes about 700 to 800 thousand tons of wood fiber per year; a plant can utilize both small diameter logs and mill by-products (with some modifications to sawmills); California is a large market for this material and the closest existing OSB plants are all well over 1,000 miles away. Key challenges to the viability of this concept are: guaranteeing adequate supply, environmental permitting issues, technical issues associated with modifying sawmills to produce OSB strands instead of pulp chips, and identifying a developer willing to take on a project that will require a substantial capital investment.

- **Small Scale Biomass with Co-Located Business(es)** – California Law SB 1122 creates an opportunity for generating heat and/or power from biomass plants that are 3 MW or smaller in size. A 3 MW plant consumes about 25,000 bone dry tons of fuel annually. Thus, the scale of such a facility is not large. However, the concept of co-locating small diameter utilizing businesses at the plants will be investigated (i.e., post and pole, shavings, firewood, briquettes, etc.). The co-located businesses will increase the amount of material that can be utilized and may provide synergies (e.g., reduced raw material costs, a thermal host, shared labor and administration, etc.). Key challenges for this opportunity are identifying sites with thermal hosts to increase revenue. In addition, the SB 1122 language requires that the fuel be forest-derived rather than less costly sources such as certain mill by-products and urban and orchard wood wastes. Thus, high fuel cost is another challenge. Third, the relatively small output of 3 MW plants compared to their capital and operating costs provide economic viability challenges.

- **Veneer – Plywood/Laminated Veneer Lumber** – are well-established technologies for producing structural building materials from veneer. They are attractive from a market perspective. The plants can utilize a component of relatively small diameter logs, but not a whole diet of small logs. The typical size plywood plant in the U.S. West consumes about 75 million board feet of logs annually. The key challenges for this technology will be finding a large enough supply of appropriately sized raw material and environmental permitting hurdles.

1.2.3 Next Steps

The second phase of the project team's work will involve detailed feasibility assessments and business planning for these four technologies. The analysis will include identifying potential sites, detailed assessments of raw material supply, developing a prototype facility for each technology and then assessing the prototype's: capital and operating expenses, product markets and sales values, permitting requirements, and evaluation of technical issues. The analysis will culminate in the creation of financial models for each technology to determine the economic viability of each prospective business. The project team will also make recommendations about next steps for further developing these concepts into actual businesses. The second phase of work will be completed by November 2015.

1.3 INTERIM REPORT – EXPANDED SUMMARY

1.3.1 California Forest Industry Infrastructure

California has 16.7 million acres of timberland located primarily in the Klamath and Northern Coast Range Mountains on the western edge of California and in the Sierra Nevada Mountain Range that extends north to south along much of the eastern edge of the state. Ownership of the timberland is roughly divided between about 50 percent National Forest and 50 percent privately held.

The state's forested land base has supported an annual timber harvest that has averaged about 1.5 billion board feet per year over the last 10 years. Harvests of 1.5 billion board feet annually are significantly lower than historic levels. For example, annual harvests averaged 5.3, 4.7, 3.9, and 2.9 billion board feet during the decades of the 60's, 70's, 80's, and 90's respectively. The infrastructure currently in place to convert the harvest into products includes about 30 sawmills, 2 veneer mills, 1 composite panel facility, about 23 biomass power facilities, and about 11 bark/mulch operations. As might be expected, the number of firms operating in California has declined significantly as the timber harvest declined.

A diversified industry infrastructure is necessary to allow by-products from one type of conversion facility to be used as feedstocks for other conversion facilities. For example, by-products of sawmilling, a foundational component of the industry, include chips that can be used for making paper, sawdust for making pellets, bark for creating landscape/mulch materials, etc. When such "secondary users" are not present, the sawmills have limited options for disposing of by-products and for obtaining additional revenue by selling those materials.

Pulp and paper manufacturing is an obvious missing industry component in California. This allows California's biomass power industry to provide sawmills with markets for the by-products that would normally be purchased by pulp and paper mills. The economics of biomass power, however, dictate that biomass power facilities offer prices for these materials that are only a fraction of their delivered value when they are utilized in the manufacture of pulp and paper.

For example, since 2010 in the Western U.S., delivered prices at biomass plants have averaged between $40 and $50 per bone dry ton.[1] In contrast, the delivered value of pulp chips in the Pacific Northwest has ranged between $80 and $140 per bone dry ton.[2] Achieving higher sales values for by-products is important to the viability of California's sawmills since they are competing in global lumber markets against manufacturers in other regions that enjoy high by-product values. While the biomass plants in California cannot pay high prices, they do, at least, offer some value and a way to dispose of the vast quantities of by-products produced at sawmills. The looming loss of more large scale biomass facilities is a serious threat to California's sawmilling industry.

To further illustrate the importance of sawmill by-products markets, **Table 1.1**, provides a comparison of pro forma income statements for "average" sawmills across North America. Please note that the U.S. West Coast category excludes California, all units are expressed on a $/MBF lumber basis, and by-product revenue is highlighted in the light green box. As shown in the figure, depending on the region, by-products comprise anywhere from 13 to 28 percent of the revenue obtained by sawmillers. The vast majority of the value of the by-products comes from the sale of pulp chips to pulp and paper mills. Unfortunately for sawmills in California there are no nearby pulp and paper mills. As a result, California sawmillers sell the material as landscape and mulch, or burn it to produce heat and power. Both provide relatively low value. Given this situation, identifying opportunities to increase the value of sawmill by-products evolved as a focus area for the project.

Table 1.1 – Sawmill By-product Revenue by North American Region
(2010 Beck Group Sawmill Benchmarking Study data; all units $/MBF lumber scale basis)

	Eastern Canada	U.S. West Coast	U.S. South	B.C. Interior	U.S. Inland West
Revenue					
Lumber	252	264	276	238	290
By-Products	**102**	**39**	**47**	**52**	**47**
Total Revenue	**354**	**303**	**323**	**290**	**337**
Log Cost (Lumber Scale Basis)	211	194	177	155	159
Labor Costs	81	42	50	52	47
Other Direct	67	39	52	48	59
Overhead/Admin	29	27	22	13	30
Total Operating Cost	**178**	**109**	**124**	**113**	**136**
Total Costs	**389**	**303**	**301**	**268**	**295**
EBITDA Margin	**(35)**	**(0)**	**22**	**22**	**41**
Depreciation/Amortization	14	14	19	14	21
EBIT Margin	**(48)**	**(15)**	**4**	**9**	**20**

[2] North American Wood Fiber Review. Published by Wood Resources International. http://www.wri-ltd.com/

1.3.2 Business Opportunity Screening Process

The project team identified nearly 50 technologies for converting various forms of wood fiber into products. The full list of technologies is shown in **Table 4.1** on page 26. A key objective of the first phase of the project was to narrow down the full technology list to 2 to 4 technologies judged to have the highest probability of being developed into viable businesses in California. To achieve that objective, the project team developed screening criteria arranged into four major categories, including: 1) commercially proven technology; 2) market attractiveness; 3) scale of operation; and 4) other/miscellaneous.

To implement the screening criteria, the project team first gathered background information about each technology. The information was documented in a series of "one-pagers" which is included in this report as **Appendix 1**. Next, the project team scored each technology using the screening criteria and the supporting information contained in the one-pagers. This resulted in the identification of the most viable technologies. However, before finalizing the results, the project team completed a review process that included gathering feedback from the project steering committee, one-on-one interviews with California forest products industry firms, and hosting a one-day workshop of forest industry stakeholders.

Raw material supply and cost is perhaps the most important aspect to the success of any forest products business. The project team intentionally excluded supply analysis from the initial screening process because many of the technologies under consideration use different raw material inputs (e.g., differing species requirements, different sizes, and different forms of wood fiber – logs, pulpwood, chips, hog fuel). Therefore, the approach taken for this project was to first identify the technologies that have been proven commercially, appear to have good markets, and are reasonably large scale. Then the supply analysis can be focused on the availability and cost for the specific type of material needed for those businesses and the analysis could be completed for the region in which such a business would logically make the most sense. Approaching the supply analysis in this way eliminates the chance of a supply study that is too general and that could potentially be focused on the wrong type of raw material. A supply analysis will be completed as an intermediate step between the technology screening and the detailed feasibility analysis and business planning. The screening methodology is described in greater detail in **Chapter 4**.

1.3.3 Opportunities Selected For Detailed Review

The project team identified each of the following technologies as having the highest probability of being developed into viable businesses in California.

1.3.3.1 <u>Cross Laminated Timber</u>

Cross Laminated Timber (CLT) is a massive, structural timber panel that is used in wall, roof, and flooring systems. The concept underlying the technology is similar to plywood – laminating layers of wood together with the wood grain in each layer oriented perpendicular to the grain in the adjacent layer(s). However, unlike plywood, which uses very thin sheets of veneer in each layer, CLT uses lumber as each layer. Panels vary in size, but a common thickness is 3 layers of dimension lumber (i.e., a panel totaling about 4.5" actual thickness). Widths and lengths also vary, but panels are commonly 8' to 10' wide, and they can be as long as 60'. The technology was developed in Germany and Austria in the early 1990's. There are currently only 3 CLT manufacturers in North America. The CLT plants developed up to this point are relatively small. However, SmartLam, a CLT manufacturer in Montana, plans to build a facility that would consume nearly 50 million board feet of lumber per year. If constructed, that plant would be the largest CLT facility in the world.[3]

The International Building Code for 2015 recognizes CLT (and other forms of mass timber) for use in multi-family, educational, commercial, industrial, retail, public, recreational, and institutional buildings. In the United States and Canada this has translated into a number of multi-story buildings being planned and currently under development using CLT. As wider code adoption among state and local authorities occurs and CLT becomes more widely specified by architects and engineers, the North American market is expected to consume 0.8 to 2.4 billion board feet of lumber per year by 2015.

California is expected to be a key region since it is a large market for earthquake retrofitting and since CLT buildings up to 7 stories tall have been shown through testing to perform very well in seismic resistance – an attribute of particular importance in California. In addition, a number of existing dimensional lumber manufacturers already operate in the region, so they can supply a CLT manufacturing operation with raw material. Finally, the presence of a CLT manufacturer(s) represents a potential new market for sawmill manufacturers, which would enhance the viability of California's sawmill industry. With regard to the cost of CLT relative to competing materials, data is not readily available. However, anecdotally it has been reported that for structures in the 4 to 8 story range, the all-in cost of CLT is comparable to using concrete and steel. However, the building shell cost is often slightly higher for CLT relative to concrete and steel.

The other advantages of CLT include panels which will typically be prefinished to very precise final dimensions, including cut-outs for windows, doors, and service channels. This is expected to translate into reduced on-site construction time and cost, smaller cranes can be used, and a building can be constructed in a fraction of the amount of time as compared to a building constructed from concrete or steel. In addition, CLT has been shown to be fire resistant since the massive timbers tend to char on the outside but retain 85 to 90 percent of their strength during the critical time required to evacuate a building in the event of fire. In addition, CLT – being made from wood – will have advantages over other building materials in building certification schemes such as the LEED program (Leadership in Energy and Environmental Design). The opportunity for CLT is more fully described in **Section 5.1**.

1.3.3.2 Oriented Strand Board

OSB is an engineered wood panel comprised of long thin "strands" that are bonded together with resin. The panels are produced in a variety of thicknesses ranging between ¼" and ¾". It is created in a variety of lengths and widths, but by far the most common are 4' wide by 8' long. The panels are most commonly used as sheathing in building wall and roof systems, but are also used as flooring and in various industrial/specialty applications.

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[3] Montana Mill to be Largest CLT Plant in the World. PanelWorld. http://www.panelworldmag.com/montana-mill-to-be-largest-clt-plant-in-the-world/

OSB facilities are large scale, typically consuming between 700,000 and 800,000 green tons of raw material per year. In addition, OSB plants typically get the majority of their feedstock in the form of small diameter logs. Thus, an OSB facility creates a significant market for the small diameter materials commonly produced in forest ecosystem restoration treatments. Currently, no markets of similar scale exist for small diameter material in California. Thus, the presence of an OSB plant would help increase the pace and scale of restoration treatments. In addition to small diameter roundwood as a supply source, there is a precedent for using sawmill downfall (e.g., slabs, edgings, trim ends, etc.) as OSB plant feedstock. The project team will investigate the feasibility of sawmills in Northern California changing their practices from producing chips from downfall to producing OSB strands. If viable, this change to current practices represents a new market for sawmill by-products which, as previously described, is critically important to maintaining the viability of sawmills.

From a market perspective, California's large housing market, represents a significant market for OSB. However, the nearest OSB manufacturers are in British Columbia (1,100 miles from Sacramento) and East Texas (about 1,800 miles from Sacramento). As a result, it is estimated that a prospective OSB plant located in Northern California would have a $25/MSF (3/8" basis) transportation cost advantage over the existing nearest suppliers.

Perhaps the largest obstacle to the development of a California OSB plant is the large capital expense, which would require a sophisticated developer and plant operator. For example, relatively recent greenfield OSB plant developments have cost about $250 million. In addition, time-consuming, expensive permitting obstacles are sure to be encountered with a project of this scale. Addressing these issues will be key focus areas of the feasibility and business planning analysis. The opportunity for OSB is more fully described in **Section 5.2**.

1.3.3.3 Small Scale Biomass with Co-Located Business(es)

The term "Small Scale Biomass" refers to a range of technologies for utilizing a variety of woody biomass types to produce heat, power, or both, and in some cases, by-products. Thus, small scale biomass can take on many forms depending on the specifics of the technology employed, the type of fuel used, and how the resulting energy is utilized. In all cases, however, such projects utilize small diameter trees and logging slash. Thus, they are projects that help increase the pace and scale of forest restoration, albeit at a relatively small scale. Revenue is generated through biomass projects by selling heat, electrical power, or both. In some cases, revenue is also generated by selling renewable energy or carbon credits. Offsetting those revenues are the capital costs for developing a biomass facility, the operating and maintenance costs associated with the facility, and the cost of the biomass fuel.

Generally, there are clear economies of scale associated with biomass projects. This is because it takes almost the same amount of labor to operate a large biomass plant as it does to operate a small plant. Thus, the smaller plant (with less capacity to produce power and, therefore, revenue) has labor costs that comprise a higher percentage of its revenue. In addition, the capital expense per unit of output drops considerably on larger projects. With smaller plants, this affects project economics negatively because they have relatively high capital costs and limited capacity to produce power/revenue to recover those capital costs. As a result, it takes a rare set of circumstances for small scale projects to be economically viable.

The project team has identified two factors that are likely to enhance the economic viability of small scale biomass projects in California. First, small scale biomass will be considered in the context of co-located businesses that will be designed to utilize various forms of small diameter forest-derived material (e.g., post and pole, animal bedding, and firewood). Those businesses may have process heat needs which would provide a market for the heat produced at a biomass plant. Secondly, those businesses may create by-products that can be used as fuel at the biomass facility. Lastly, these businesses create additional value from the fuel flow to the biomass heat/power facility.

Second, California Senate Bill 1122 requires California's investor owned utilities (IOU's) to purchase 50 MW of renewable power from the by-products of sustainable forest management. Given that Pacific Gas & Electric's service territory coincides with the most heavily forested area in the state, that utility is responsible for 47 of the 50 MW requirement. No single project in the program can be larger than 3 MW. As a rule of thumb, each MW of capacity requires about 8,000 bone dry tons of fuel annually. Thus, a 3 MW facility would likely consume about 25,000 bone dry tons of fuel per year. If the IOU's fully comply with SB 1122, a number of small scale biomass plants will be developed and, in aggregate, they would have an appreciable effect on the pace and scale of forest ecosystem restoration efforts.

SB 1122 also specifies the starting price that the IOU's must offer for the power produced. If no projects find that price acceptable, there is a mechanism by which the price will increase until one of the project developers accepts the price. The opportunity for small scale biomass is more fully described in **Section 5.3**.

1.3.3.4 Veneer – Plywood/Laminated Veneer Lumber (LVL)

Peeling veneer from softwood logs is the first step in producing raw materials for a variety of the technologies being evaluated by this project, including plywood and LVL. Traditionally, relatively large logs have been used to manufacture veneer. However, in recent years, veneer producers in Oregon, Washington and California have successfully produced veneer from relatively small logs (e.g., logs with an average diameter of 8 inches and a minimum diameter of 6 inches). Thus, this technology, provides a means of increasing the pace and scale of forest ecosystem restoration efforts if designed to utilize at least a percentage of small diameter logs as feedstock,.

Two veneer plants are currently operating in Northern California. However, the veneer produced at those plants is shipped to Southern Oregon where it is manufactured into various products, including plywood and LVL. Thus, this technology could bring the value adding aspects of plywood and LVL manufacturing to an operation in California.

Plywood and LVL were selected because the market outlook for both of these materials is relatively strong. For example, the existing North American plywood plants are operating at about 90 percent of capacity and demand for plywood is projected to increase about 14 percent in 2016. Similarly, for LVL, a material that is commonly used as the flange in wooden I-joists, the market is expected to grow as housing starts increase and as a shortage in 2" x 3" lumber develops (2" x 3" lumber is a substitute I-joist flange material). 2 x 3 lumber is generally manufactured in Eastern Canada where the sawmilling industry is encountering difficult operating conditions due to a reduced annual allowable cut and the closure of numerous pulp and paper facilities.

Veneer manufacturing and its subsequent use in plywood or LVL requires the material to be dried. Drying requires some type of heat source, which most commonly in the forest products industry is a wood-fired boiler. Thus, environmental permitting associated with this technology is expected to be a key focus area in the feasibility and business planning study phase. The opportunity for Veneer – Plywood/LVL manufacturing is described in greater detail in **Section 5.4**.

CHAPTER 2 – INTRODUCTION

The National Forest Foundation (NFF) is a non-profit organization whose mission is to lead community-based and national programs aimed at restoring and enhancing National Forests in the United States. As part of the mission, NFF entered into a Cooperative Agreement with the U.S. Forest Service Region 5 (Pacific Southwest Region) to administer funds for the *California Assessment of Wood Innovation Opportunities and Markets*. NFF issued a Request for Proposals (RFP) seeking the expertise and services necessary to:

1. Assess, analyze, and interpret the current status and trends of California's wood products industry and markets.
2. Identify business opportunities that will help the U.S. Forest Service increase the pace and scale of forest ecosystem restoration.
3. Identify gaps and weaknesses in policy, environmental, and social concerns related to the opportunities identified.
4. Prepare realistic business plans with clear actionable items to implement the most promising business opportunities.

In response to the RFP, The Beck Group (BECK), a forest products planning and consulting firm based in Portland, Oregon, formed a Consulting Team that includes Carlson Small Power Consultants (CSPC), a biomass heat and power consulting firm based in Redding, California; Mason, Bruce, & Girard (MB&G), a natural resources consulting firm based in Portland, Oregon; and Fido Management (FIDO), a business management consulting firm based in Davis, California. Each Consulting Team member brings to the project specific skills and knowledge pertinent to achieving the objectives of the RFP.

This report is the first of two deliverables that will result from this project. It contains:

1. A review of the status of California's forest products industry.
2. A description of the business opportunities selected for detailed analysis.
3. A description of the business opportunity screening methodology.
4. A listing and brief description of each of the business opportunities considered.

The second (not yet completed) deliverable from the project will be a report describing a detailed business feasibility analysis and business planning for each of the most promising business opportunities. The second report will also contain recommendations about the next steps needed to implement the business opportunities identified.

CHAPTER 3 – CALIFORNIA FOREST INDUSTRY INFRASTRUCTURE REVIEW

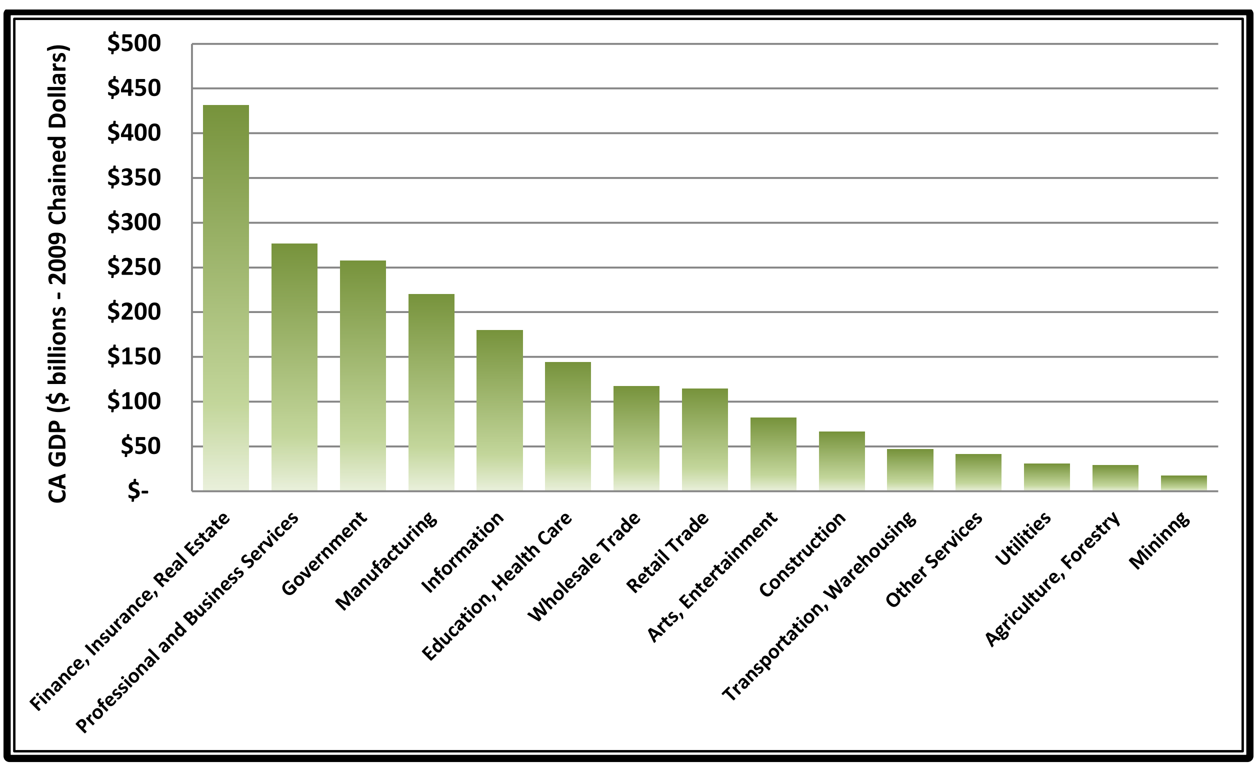
The following chapter provides a review of the current status and trends in California's wood products industry.

3.1 FOREST PRODUCTS WITHIN CALIFORNIA'S ECONOMY

With a population of 38.8 million in 2014, California accounts for about 12 percent of the U.S. population. California accounts for a similar proportion of the Nation's economic output: California's GDP of about $2 trillion in 2013 accounted for about 12 percent of the Nation's $16.7 trillion GDP. Expressed another way, in 2013, California's GDP was ranked 9th largest in the world – bigger than any other U.S. state and larger than most other countries. Texas, the U.S. state with the next largest economy, had a gross domestic product in 2013 of $1.3 trillion.

Figure 3.1 displays the relative contribution of various sectors to California's GDP. Note that Agriculture and Forestry combined accounted for about $29 billion of value added to California's GDP. At the primary forest products level, California's forest products industry generated $1.4 billion in revenue in 2012, with lumber sales accounting for about 66 percent of the total. Thus, despite forests covering a significant portion of the state's land area (as will be shown in a later section), the forest products industry is a relatively small part of California's economy in terms of GDP.

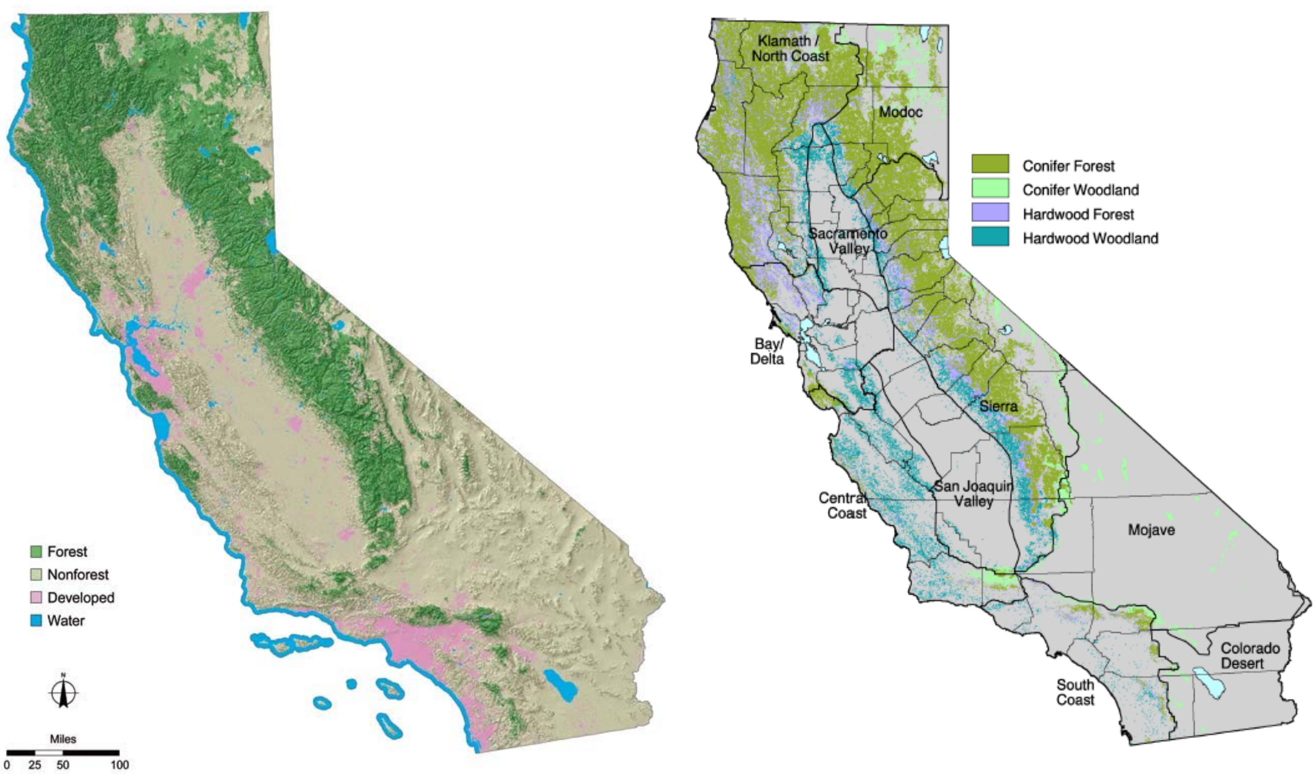
Figure 3.1 – 2013 Gross Domestic Product in California by Industry (2009 Chained U.S. $ in billions)



3.2 THE FOREST RESOURCE IN CALIFORNIA

The total land area in California is 99.6 million acres, which makes it the third largest state in total land area behind Alaska and Texas. According to the U.S. Forest Service Forest Inventory and Analysis database, of the total land area, 32.2 million acres are classified as *forestland*[4] and 16.7 million acres are classified as *timberland.*[5] **Figure 3.2** displays the distribution of forested land within the state. As shown, forest lands are generally concentrated in the northern portion of the state and in the Sierra Cascade Mountain Range that extends north to south across much of the State. In addition, the figure shows the distribution by forest type. Note that while deciduous species have a relatively wide geographic distribution, they only account for about 8 percent of the total sawtimber volume in the State.

Figure 3.2 – Distribution of Forests & Forest Type within California



Source: U.S. Forest Service Pacific Northwest Research Station and The Changing California Forest and Range Assessment, 2003.

[4] Forest land is defined as "land that is at least 10 percent stocked by forest trees of any size, or land formerly having such tree cover, and not currently developed for a non-forest use".

[5] Timberland is defined as "land that is producing or capable of producing 20 cubic feet of wood fiber per acre per year at the culmination of mean annual increment and excludes reserved lands such as National Parks and Wilderness Areas"

Table 3.1 displays the proportion of California's forests owned by different landowner groups, both in terms of forestland and timberland. It is important to note that National Forest accounts for about 50 percent of the forest in the state and privately owned forest accounts for about 40 to 45 percent of the area (depending on whether its forestland or timberland).

Table 3.1 – Ownership of California Forestland and Timberland

Ownership Group	Forestland Acres	% of Total	Timberland Acres	% of Total
National Forest	15,429,961	48	8,905,303	53
Private	12,541,005	39	7,357,337	44
Bureau of Land Management	1,557,441	5	332,777	2
National Park Service	1,426,743	4	0	0
State	698,783	2	85,699	1
County and Municipal	364,002	1	37,531	0
Fish and Wildlife Service	4,171	0	0	0
Department of Defense	92,639	0	13,316	0
Other federal	119,187	0	0	0
Other Local Government	19,971	0	0	0
Total	**32,253,903**	**100**	**16,731,963**	**100**

The private ownership of timberland can be further subdivided into non-industrial private forestlands (NIPF) and industrial forest landowners. The NIPF owners account for about 3.2 million acres compared to about 4.2 million acres of timberland owned by the forest industry.[6] The geographic distribution of the industrial timberlands include 1.4 million acres in the North Coast region, 1.7 million acres in the Northern Interior region, 0.9 million acres in the Sacramento region, 0.15 million acres in the San Joaquin/South region of the state, and 0.02 million acres in the Central part of the state. Some of the companies that comprise the industrial ownership include: Sierra Pacific Industries, Green Diamond, Collins Companies, Roseburg Forest Products, Fruit Growers Supply, Timber Products, Mendocino Forest Products/Humboldt Redwood Company.

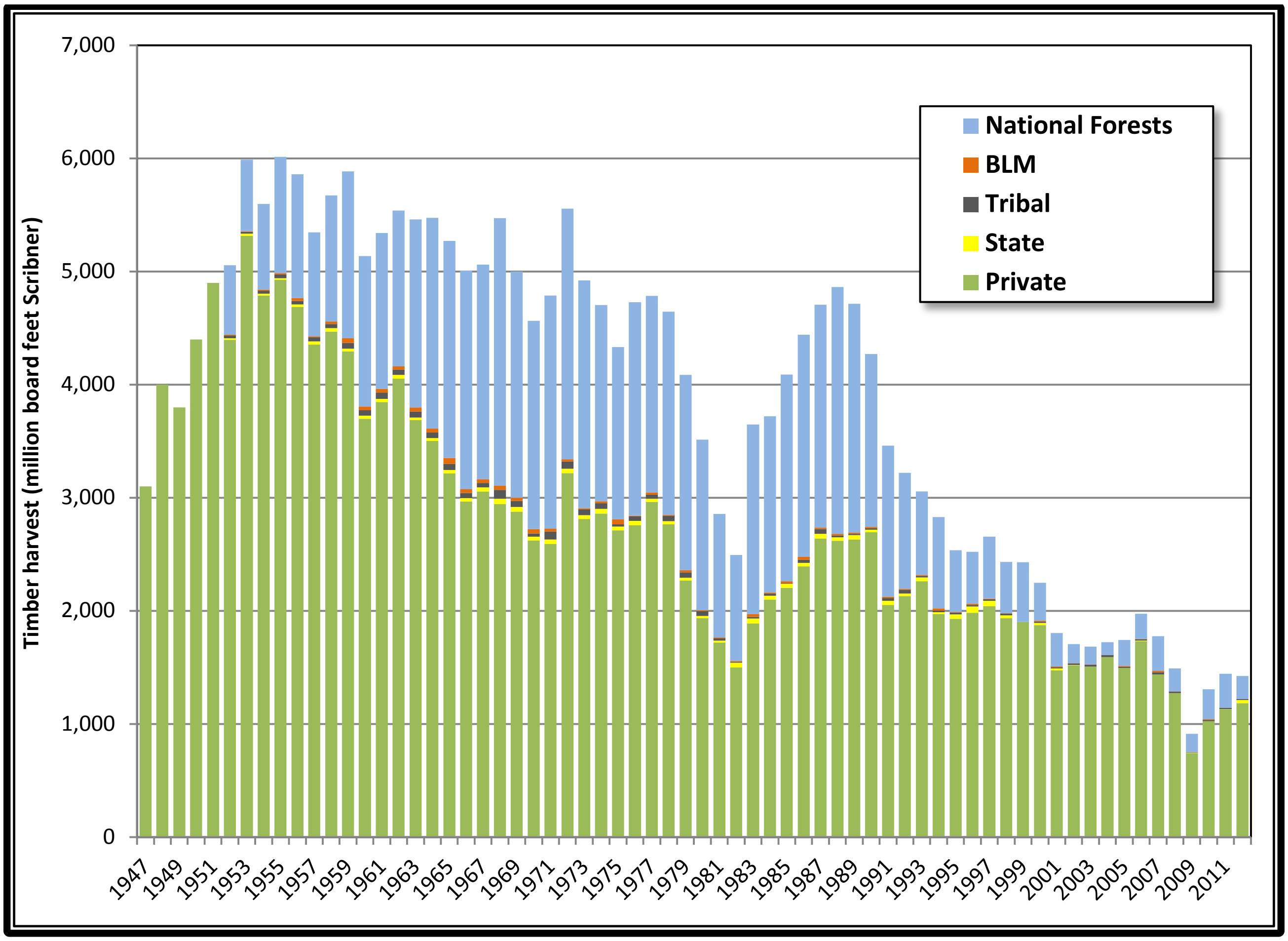
3.3 CALIFORNIA TIMBER HARVEST

Figure 3.3 displays the source of California's timber harvest (by landowner type) from 1947 to 2012. As the figure shows, the overall timber harvest has steadily declined over the period from highs of

[6] Non-Industrial Timber Management Plans in California. (2003) Accessed at: http://www.fire.ca.gov/resource_mgt/downloads/NTMPReport_FINAL_10.23.03.pdf

about 6.0 billion board feet[7] to current levels of about 1.4 billion board feet per year. While harvest volumes have declined across all ownerships, the declines have been most significant from National Forests – especially over the last two decades. Between 1959 and 1993 the private harvest averaged 60 percent of the total compared to 37 percent from National Forests. Since 1993, the private harvest has averaged 82 percent of the total compared to 17 percent from National Forests. It is important to note that the harvest proportion does not match the ownership proportions. Some of the reason may be that privately owned forests are more productive, but the main reason is that management of National Forests is hamstrung by policy issues. This topic will be addressed in more detail in this project's final report.

Figure 3.3 – Annual Timber Harvest in California by Landowner Type (Millions of Board Feet)



The University of Montana Bureau of Business and Economic Research has completed periodic reviews of the forest products industry for a variety of states in the U.S. West. The most recent report on California provides an overview of the industry during 2012.[8] Regarding the geographic

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[7] A board foot is a common unit of measure in the forest products industry. It refers to a volume of wood that equals 1" thick by 12" wide by 12" long.

[8] California's Forest Products Industry and Timber Harvest, 2012. University of Montana Bureau of Business and Economic Research, accessed at: http://www.bber.umt.edu/FIR/default.asp

distribution of the 2012 timber harvest within the state, about 55 percent came from a five county region in the northern part of the state, including Shasta (229 MMBF), Humboldt (215 MMBF), Siskiyou (148 MMBF), Mendocino (109 MMBF), and Lassen (84 MMBF).

Regarding the proportion of the 2012 timber harvest by species, Douglas fir was about 29 percent of the total, true firs comprised about 27 percent, ponderosa pine was about 18 percent, redwood totaled about 15 percent, and sugar pine comprised about 6 percent. These proportions by species have been relatively consistent over time. Finally, with regard to the type of products harvested, sawlogs accounted for 82 percent of the harvest volume, veneer logs accounted for about 10 percent, and bioenergy (small diameter logs) accounted for about 8 percent of the harvest volume. Those proportions observed in 2012 are in line with historic averages, although the harvest of veneer logs is up slightly from historic levels.

3.4 PRIMARY FOREST PRODUCTS PROCESSING INDUSTRY

The University of Montana BBER report also provides information about how the timber harvested in California is utilized. Please note that in order to better understand the status of California's forest products industry comparisons are drawn to Oregon's forest products industry.

Table 3.2 provides a comparison of the number of firms operating in different sectors of the forest products industry in each state. As shown in the table, the number of forest products firms in both states has declined by about 70 percent over the time period. Oregon, however, has maintained diversity in the types of facilities operating in the state. Note that the "other" category in California includes log home producers, shake and shingle producers, wood pellet mills, and post and pole producers. Also note that the "other" category in Oregon includes biomass energy, bark/mulch/compost products, wood pellets, cedar products, and log home products.

Improvements in processing efficiency mean that the decline in the number of firms is not directly correlated to the output of the industry. For example, according to BBER's report, the sawmill industry in California improved recovery (the ratio of lumber volume to log volume) from 1.14 in 1968 to 1.63 in 2012. This means that the 5.3 billion board feet log harvest in 1968 could have been converted into about 6.1 billion board feet of lumber. In 2012, the 1.43 billion board feet of log harvest could have been converted into 2.3 billion board feet of lumber. Thus, the improved efficiency has somewhat offset the lower harvest levels.

In terms of dollars, the revenue of the industry has declined. For example, in 1990 the total sales value of forestry and logging, forestry support activities, wood products manufacturing, and pulp and paper manufacturing was $5.4 billion (adjusted to a 2012 basis). By 2012, the sales value of the same sectors had fallen to $3.3 billion (2012 dollar value basis).

Table 3.2 – Comparison of Forest Products Industry Mill Infrastructure between CA and OR (Number of Processing Facilities by Industry Sector)

Industry Sector	California (1968)	California (2012)	Oregon (1968)	Oregon (2013)
Lumber	216	30	300	88
Veneer/Plywood	26	2	168	26
Pulp/Paper and Board	17	1	37	19
Bioenergy	0	26	0	0
Bark/Mulch	0	11	0	
Other	3	7	48	35[9]
Chipping	0	0	0	11
Post and Poles	0	0	0	9
Total	**262**	**77**	**553**	**188**

3.4.1 Raw Material Flow and Final Disposition in California

Similar to the comparison between Oregon and California made in the preceding table, the following figures compare what types of facilities the raw materials *flow into* in Oregon and California as compared to the types of products that *flow out* of those facilities. In other words, the following figures provide insight into how the forest products firms in California and Oregon utilize the wood fiber that is produced in each state. It is important to note that the analysis is on the volume and type of material flowing in compared to the volume and type of material flowing out. This differs from the dollar value of the material flowing in versus the dollar value of the material flowing out. For example, as will be shown in the following figures, lumber in California is a relatively small proportion of the volume of material produced in the state, but it is the single greatest value material produced in the state.

Figure 3.4 shows how the material harvested from California's forests flows into forest products manufacturing facilities. In other words, of the 420 million cubic feet of material harvested in California in 2012, 61 percent of that volume went into sawmills, 31percent to biomass energy, and 8 percent to veneer mills.

[9] The "Other" category for Oregon includes biomass energy, bark/mulch/compost products, wood pellets, cedar products, and log home products.

Figures 3.4 – Raw Material Inputs: Forest to California Mills (Percent of Volume)

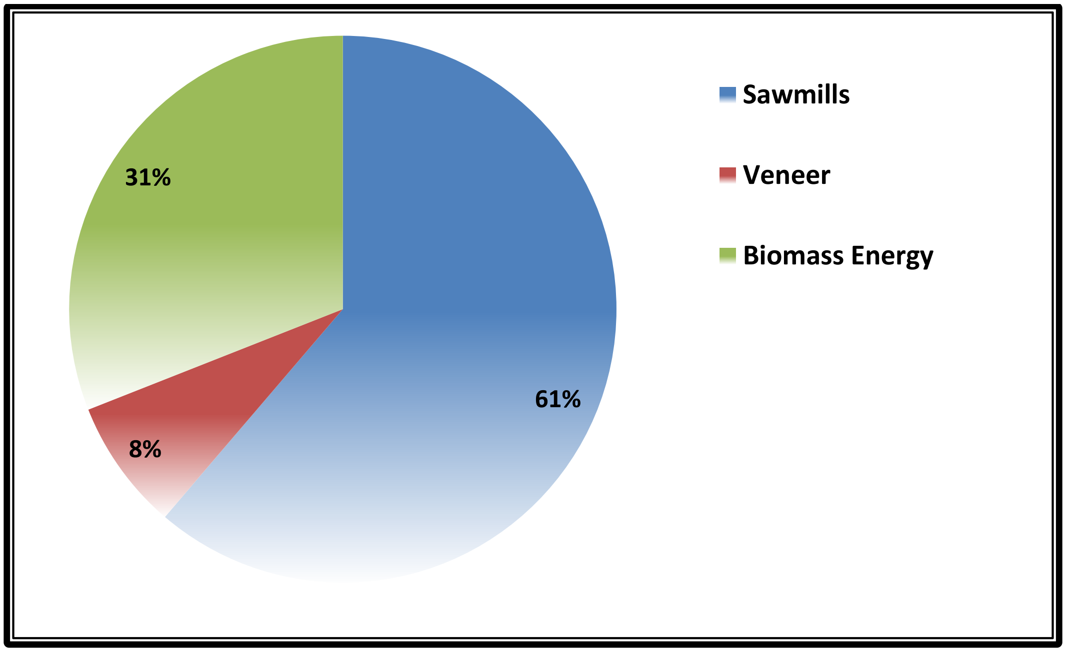
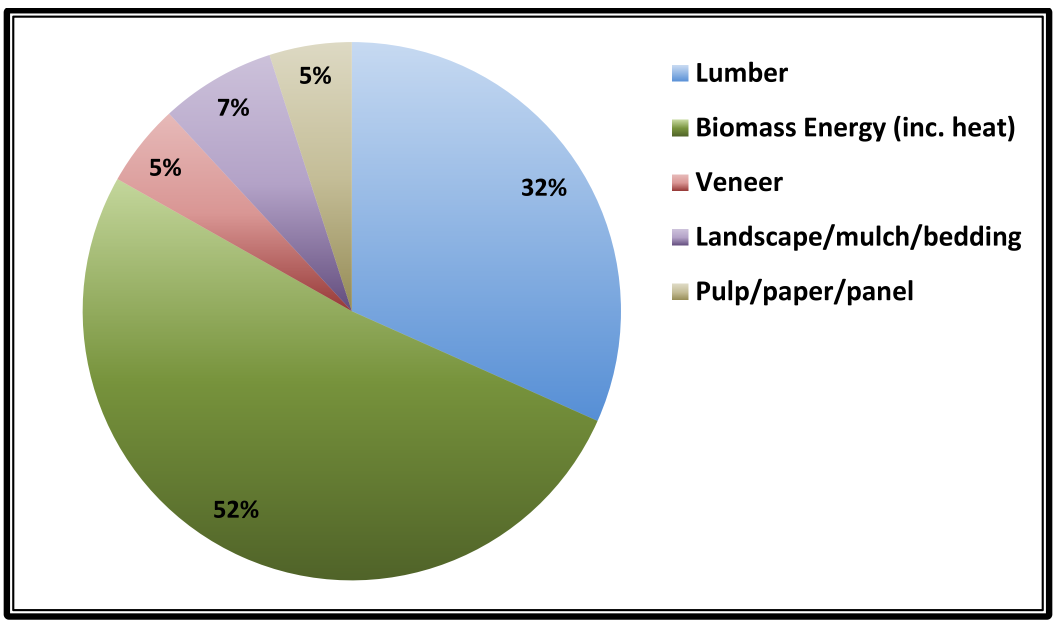


Figure 3.5 shows the final disposition of the materials that flow into processing facilities in California (volume basis). As the figure shows, nearly three quarters of the material that flows into mills in California goes into sawmills. However, the sawmills convert less than half of that material into lumber, with much of the balance going into biomass energy, landscape/mulch/bedding, and the panel industry. Please note that there is no remaining pulp and paper industry in California, but to allow for time series comparisons in the data there is still a pulp/paper/panel category.

Figure 3.5 – Final Disposition of Raw Materials Input into California Mills (Percent of Volume)



The two preceding figures depict the flow of raw material into mills to the final disposition of products out of mills in California. The analysis was on the basis of volume. **Table 3.3** shows the relative value of the various products produced in 2012. Note that despite lumber only accounting for 32 percent of the volume of materials produced, it comprises 64 percent of the value. Biomass energy, on the other hand, accounted for 52 percent of the volume, but only 24 percent of the value. Thus, a large portion of the material flowing from the woods to mills in California is being utilized in a low value application. Finally, the pulp/paper/panel and landscape/mulch/bedding categories from **Figure 3.5** are all combined in the Residue Utilizing Sector category in **Table 3.3**.

Table 3.3 – Sales Value of Products Produced at California's Primary Processing Mills

Product Type	Dollar Value (000's)	Percent of Total
Lumber	876,389	64
Biomass Energy	327,458	24
Veneer	44,328	3
Residue Utilizing Sector	122,770	9
Total	**1,370,945**	**100**

3.4.2 Raw Material Flow and Final Disposition in Oregon

As a point of comparison, **Figure 3.6** shows where the material harvested from Oregon's forest flows into forest products manufacturing facilities. In the case of Oregon, there was a total of 1.283 billion cubic feet of raw material flowing into conversion facilities in 2013. As shown in the table, nearly half of the material went to sawmills versus the 72 percent of the raw material that went into sawmills in California. A key difference between California and Oregon is that in Oregon 28 percent of the harvest volume went to pulp/paper and board mills and only 12 percent went into the "other" category, which includes biomass energy. In California, there is only 1 composite panel plant (e.g., medium density fiberboard, particleboard, hardboard) and no pulp and paper facilities. Thus, a much higher percentage of the raw material harvested flowed into biomass energy facilities in California.

Figure 3.6 – Raw Material Inputs: Forest to Oregon Mills (Percent of Volume)

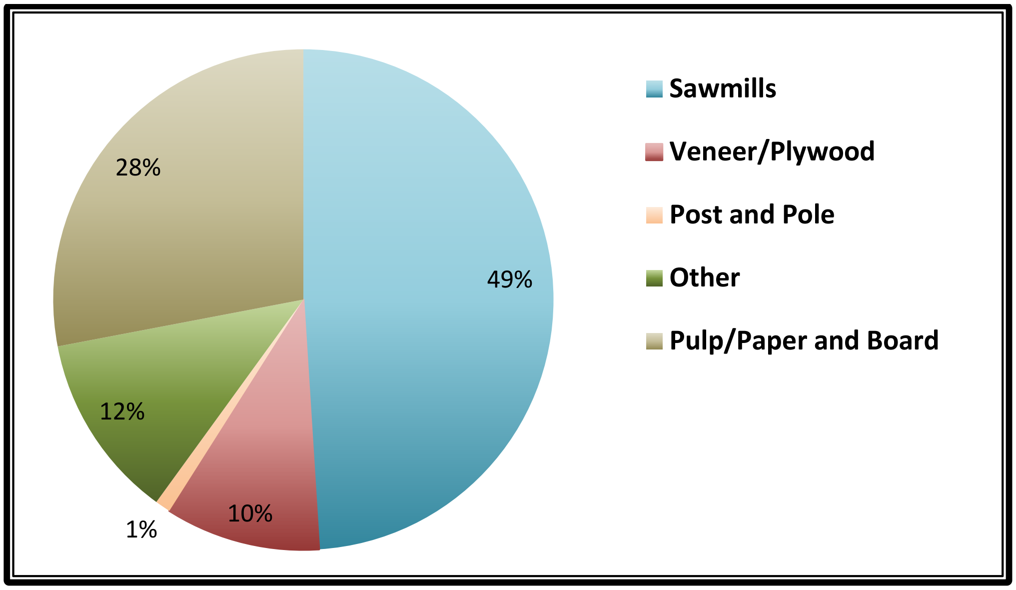
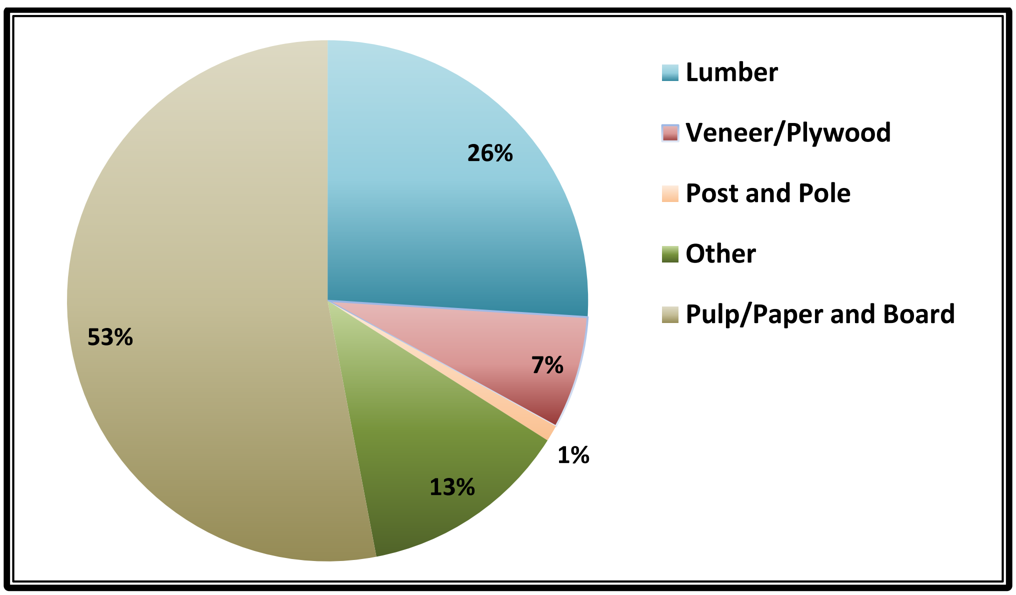


Figure 3.7 displays where the raw materials that flowed into Oregon conversion facilities ended up as final products. Note that, unlike California, Pulp/Paper and Board accounts for the highest proportion of the fiber disposition in Oregon. Also note that the Other category in Oregon includes biomass energy and is only 13 percent of the fiber disposition in Oregon.

Figure 3.7 – Final Disposition of Raw Materials Input into Oregon Mills (Percent of Volume)



The two preceding figures depict the flow of raw material into mills to the final disposition of products out of mills in Oregon. The analysis was on the basis of volume. **Table 3.4** shows the relative value of the various products produced in 2013. Despite lumber only accounting for 26 percent of the volume of materials produced, it comprises 41 percent of the value. Pulp/Paper and Board, on the other hand, accounts for 53 percent of the volume, but only 30 percent of the value. This is likely due to the panel products (e.g., particleboard and medium density fiberboard) being relatively low value, but using relatively high volumes of material. Perhaps, most remarkable is that veneer and plywood only consume about 7 percent of the volume in Oregon, but deliver 22 percent of the value.

Table 3.4 – Sales Value of Products Produced at Oregon's Primary Processing Mills

Product Type	Dollar Value (000's)	Percent of Total
Lumber	3,049	41
Pulp/Paper and Board	2,286	30
Veneer/Plywood	1,650	22
Post and Pole	61	1
Other	467	6
Total	**7,513**	**100**

The six preceding tables and figures for Oregon and Washington are summarized in **Table 3.5**. Note that the inputs and disposition are expressed as a percent of volume. The value column is expressed as a percent of the overall dollar value (f.o.b. mill gate) generated by the industry.

Table 3.5 – Summary of Oregon and California Forest Products Industry Comparison

	California				Oregon		
	Inputs	Disp.	Value		Inputs	Disp.	Value
Sawmills/Lumber	61	32	64	Sawmills/Lumber	49	26	41
Veneer	8	5	3	Veneer/Plywood	10	7	22
Biomass Energy	31	51	24	Post and Pole	1	1	1
Landscape/mulch/bedding	n/a	7	9	Pulp/paper and Board	28	53	30
Pulp/paper/panel	n/a	5	n/a	Other	12	13	6
Total	**100**	**100**	**100**	**Total**	**100**	**100**	**100**

3.5 DISCUSSION OF KEY OBSERVATIONS

3.5.1 Raw Material Supply

Raw material supply is the most critical issue leading to an overall decline in the size and economic contribution of California's forest products industry. Conversion facilities simply will not continue operating, or be constructed, when raw material supplies are declining. According to interviews conducted by the project team with industrial timberland owners in California, they are harvesting and replanting their forests at rates that are sustainable over the long-term. In other words, the annual harvest is in balance with annual growth on industrial timberlands in the state. Thus, there is limited capacity for the industrial timberland owners to increase the supply by harvesting more trees.

The interviews also revealed at an anecdotal level that non-industrial private timberland owners in California struggle to cost effectively comply with the forest management laws currently in effect in the state. As a result, many of those types of landowners elect to not manage their forests because it is too costly. Again, this trend is reported anecdotally. However, if true, it makes California the only state in the West where the non-industrial private timberland harvest is not a significant part of the supply equation. National Forests clearly offer another alternative for increasing the supply of raw material available to California's forest products industry.

3.5.2 California Biomass Power Industry Infrastructure

As described earlier in this chapter, biomass power is a critical component of California's forest products industry. The Public Utilities Regulatory Policies Act (PURPA) was enacted in 1978 as a means of promoting greater production of renewable energy. California's interpretation and implementation of this law led to the development of a portfolio of biomass fueled power plants in California during the 1980's. The industry peaked between 1990 and 1993 when 66 facilities with a total capacity of 800 MW were operating.[10] Today, about 23 facilities with a combined capacity of about 410 MW are still operating. During the industry's peak, plants were converting about 10 million bone dry tons of biomass per year into about 2 percent of California's electric supply. Today, the remaining facilities convert an estimated 3.3 million bone dry tons of biomass into electricity.

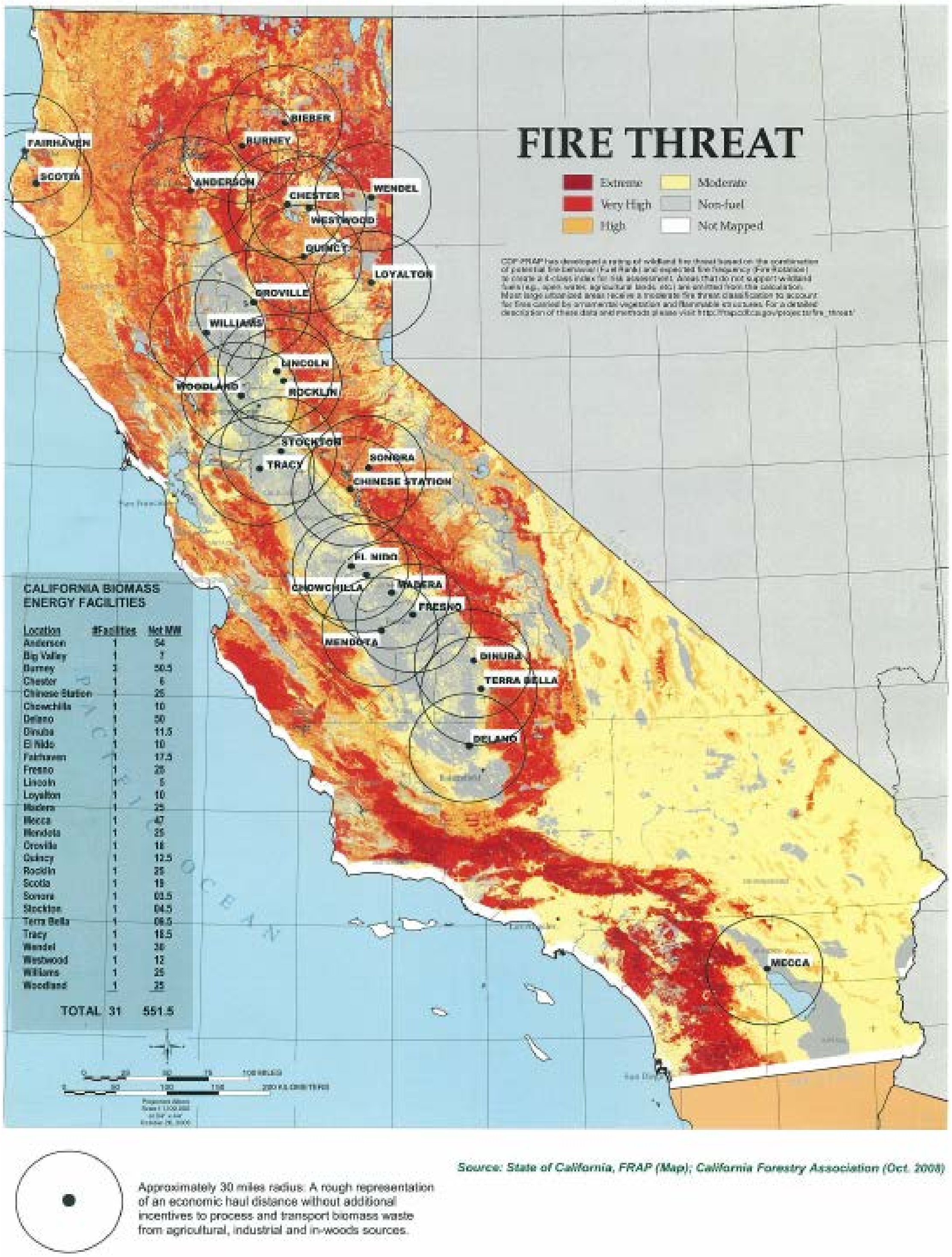
Converting biomass into electricity is important for several reasons. First, it provides a means of disposing of significant volumes of biomass material that is otherwise: open burned with no controls to reduce emission of particulates and greenhouse gases; or accumulates in forests as fuel to feed potential wildfires. Second, it provides opportunities for rural development and job creation in economically depressed regions. Third, the quantifiable economic value of these benefits is estimated to be greater than the cost of the electricity produced from biomass.[11]

[10] Biomass Energy in California. http://www.energy.ca.gov/biomass/biomass.html.
[11] Biomass Energy Production in California: The Case for a Biomass Policy Initiative. Gregory Morris. 2000. Accessed at: http://www.nrel.gov/docs/fy01osti/28805.pdf.

Figure 3.8 illustrates the locations of the California Biomass Energy facilities (circa 2008) overlaid on a fire threat map. As shown in the figure, with the exception of the southern coast range, the location of the biomass facilities is well aligned with the areas having the largest wildfire threat. Note, however, that since 2008, when the map was developed, 8 facilities, representing about 150 MW of capacity, have ceased operations, but the assets are still in place and could be revived. The continued existence of California's remaining biomass plants is threatened. This is primarily due to the fact that the 25 to 30 year power purchase agreements between the biomass plants and utilities are now coming up for renewal. Those contracts were structured to initially pay the biomass producers relatively high prices for energy and capacity during the first ten years of each contract. However, for the last two-thirds of the contracts, utilities are only required to pay market rates for energy from the biomass facilities. Current low natural gas prices mean that market rates for energy are too low for the biomass plants to cost effectively renew their contracts. In addition, new wind and solar power incentives differ from and are greater than those available to biomass. As a result, the biomass power facilities are closing as their existing contracts expire.

Thus, if the State of California's biomass industry is to survive, policy support that recognizes the environmental and other benefits associated with biomass power and that provides a means for sharing the higher cost of biomass power is needed in order to allow everyone to enjoy the associated environmental benefits. Finally, it is worth noting that despite the current fleet of facilities at or approaching 3 decades in age, the facilities can operate several more decades if power sales contracts that allow the owners to properly maintain and update the facilities are sanctioned.

Figure – 3.8 California's Biomass Energy Industry (circa 2008) and Fire Threat (circles around each plant represent the economically feasible haul distance)



3.5.3 Fruit Growers Supply Company Sawmill in Yreka

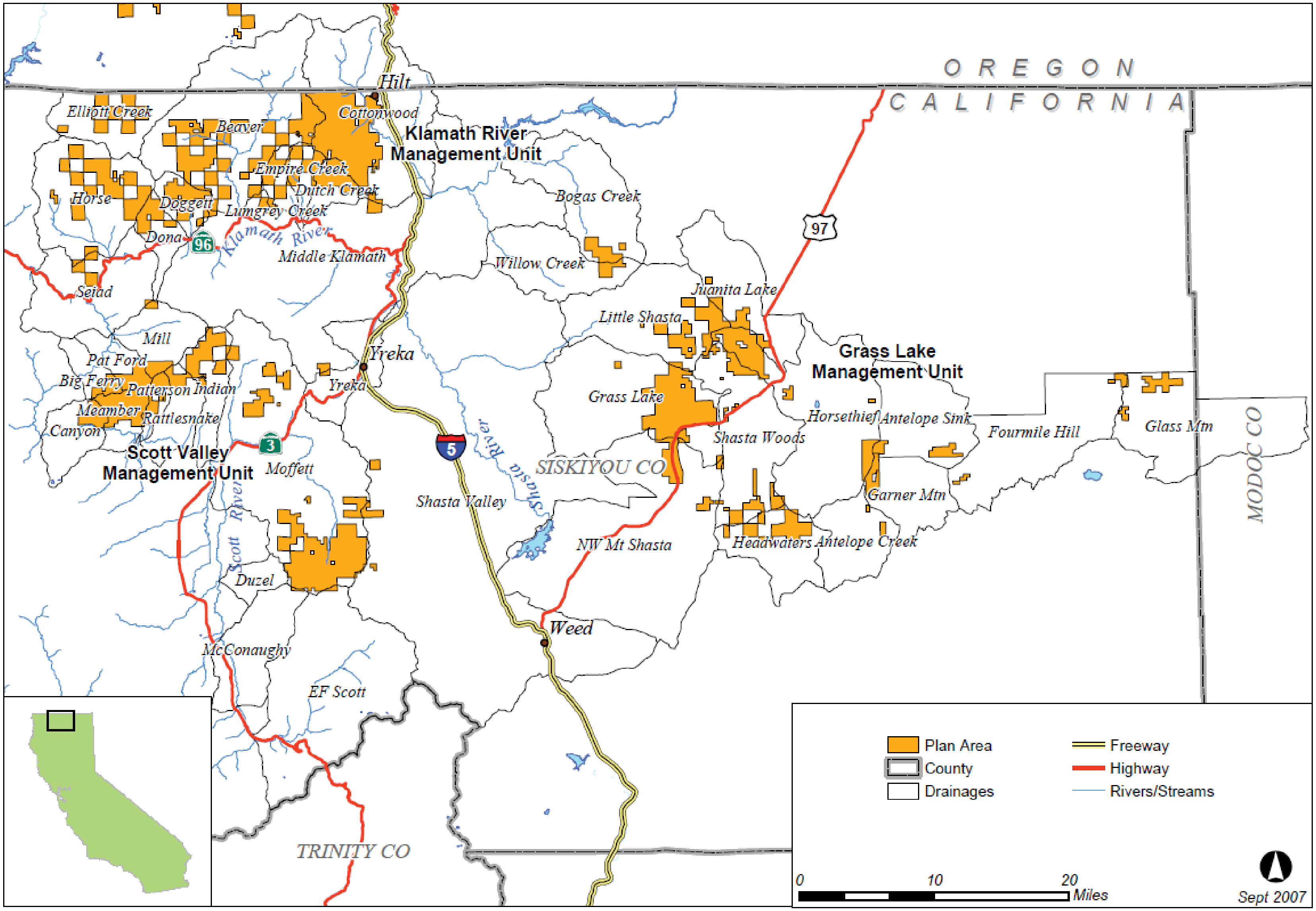
As described earlier in this chapter, sawmill closures and a dwindling number of operating facilities are a clear trend in California's forest products industry. However, countering this trend is Fruit Growers Supply Company (FGS), a California timberland owner, currently developing a small log sawmill in Yreka, California. FGS operated a sawmill in Hilt, California for many years but it was permanently closed in 1974. That mill processed large logs primarily to produce lumber for the manufacture of wooden shipping crates then used by its member owners. In the forty plus years since that mill closed, the company shifted focus of its forestry operations to growing and selling timber to unaffiliated mills. However, FGS's ownership of timberland coupled with its production of pallets for its member owners, and its unique cooperative structure have now led to the sawmill project.

Regarding FGS as a timberland owner, the company manages approximately 152,000 acres of timberland in Siskiyou County, California (**Figure 3.9**). As shown in the figure, Yreka is centrally located among those timberland holdings, which are organized into three management units including the Scott Valley Management Unit, The Klamath River Management Unit, and the Grass Lake Management Unit. FGS timberlands are managed on a sustained yield basis. The company maintains two timberland management offices in California. One is located in Hilt for oversight of the three management units discussed above. The other is in Burney for management of timberlands in Shasta and Lassen Counties. In addition, FGS has offices in Springfield, Oregon and Montesano, Washington to manage timberlands in those states.

Existing sawmills and veneer/plywood operations in Northern California and Southern Oregon have provided markets for sawlogs - typically logs at least 8 inches in SED (small end diameter) and at least 16 feet long. However, markets for chip-n-saw size logs (between 4" and 8" SED) are much harder to find. One of the few options is selling logs between 6" and 8" SED to the Timber Products veneer mill in Yreka. This "hole" in the log market is a key driving factor in FGS developing a mill designed to better utilize the small diameter logs produced in the region. The mill will process logs with a minimum 3.5" SED up to a maximum large end diameter of 12". The minimum long length is 10 feet. Production at the mill is expected to be 25 to 30 million board feet (1 shift basis) per year.

FGS was formed in 1907 as a supply cooperative to assist member citrus growers and packing houses in California and Arizona. Farmers and packing houses that are cooperative members purchase supplies (i.e., products to assist in the growing, packing, and marketing of their crops) from the cooperative at cost. Pallets for both members and open market customers are produced at FGS's pallet manufacturing and distribution facility in Visalia, California. The Visalia operation consumes about 30 million board feet of lumber per year. Pallets can be manufactured at Visalia using lumber produced at the FGS sawmill in Yreka from trees grown on FGS's timberland. This unique circumstance is another key driver in the development of the sawmill. As of late spring 2015, the mill is under construction, and the company has begun accumulating sawlogs in the mill's log yard.

Figure 3.9 – Fruit Grower's Supply Northern California Timberland Holdings



CHAPTER 4 – BUSINESS OPPORTUNITY SCREENING PROCESS

This chapter provides a listing of the potential business opportunities considered and a description of the screening methodology used to narrow the list to a few selected for detailed analysis.

4.1 LISTING OF POTENTIAL BUSINESS OPPORTUNITIES

Table 4.1 identifies the full list of potential business opportunities for converting wood raw materials (e.g., logs, pulpwood, mill residuals, logging slash, etc.) into products. The list was organized into four technology categories consisting of: 1) Energy Related; 2) "Traditional" or Engineered Wood Products; 3) By-Products Users; and 4) Other. The list was derived from a combination of prior work completed by the US Forest Service, the consulting team's experience, and suggestions made by the project steering committee and industry contacts.

Table 4.1 – Full Listing of Business Opportunities Considered for Detailed Analysis

Energy Related	"Traditional" and Engineered Wood Products	By-Products Users	Other
Small Biomass CHP	Laminated Veneer Lumber (LVL)	Air Filtration Media	Activated Carbon
Butanol/Drop in fuels	Fencing	Animal Bedding	Anaerobic Digestion
Cellulosic Ethanol	Finger-jointed Lumber	Compost/Mulch	Biochar
Charcoal	Glulam	Decorative Bark	Cross Laminated Timber
Firewood	Large Scale Sawmill	Decorative Chips	Emerging Bioproducts
Fuel Bricks/Logs	Medium Density Fiberboard	Hardboard	Erosion Control
Large Scale Biomass Power	Oriented Strand Board (OSB)	Liquid Filtration Media	Excelsior
Pyrolysis	Parallam	Whole Log Chips	Extractives
Small Biomass w/o CHP	Particleboard	Wood Plastic Composites	Nanocellulose
Small Gasification CHP	Plywood		Scrimber
Small Gasification w/o CHP	Post and Pole		
Torrefied Wood Pellets	Pulp and Paper		
Wood Pellets	Semi-Mobile Sawmill		
	Shingles		
	Small Scale Sawmill		
	Wooden I-Joists		

4.2 SCREENING CRITERIA

The screening criteria applied to the list of technologies were developed by the consulting team. Each criterion used had an associated point value. Some criterion were scored as “-1” if the technology did not meet the criterion, a “1” if the technology did meet the criterion, or “0” if the team was not able to definitively determine whether the technology did or did not meet the criterion. For other criteria, a scale between 0 and 5 was used to reflect different levels at which a given technology met a given criterion. For each technology the scores from the various screening criteria were totaled. The technologies with the highest scores were judged to have the greatest potential for being developed into viable businesses.

The criteria were divided into 4 major categories, including:

1. **Commercially Proven Technology**: There is a very important distinction between being “technically possible” and “commercially proven”. Technologies in the former category, while perhaps having the potential to be viable businesses, were excluded from further analysis because businesses based on those technologies would not be able to obtain financing for the project (through normal channels) or obtain performance and environmental guarantees from the technology vendor.

   The specific criteria used included:

   - The Technology proposed must have been demonstrated in a commercial setting, at commercial scale, for at least two years. *(Scoring: -1, 0, or 1).*
   - The Technology supplier/developer must be able to offer commercial warranties as to performance, environmental compliance and completion, and must be able to bond such warranty through commercial sources. *(Scoring: -1, 0, or 1).*
   - The business/technology must be capable of being financed through normal commercial channels, with debt/equity ratios in line with other Technologies of similar risk. *(Scoring: -1, 0, or 1).*

2. **Market Attractiveness:** The products produced by a given technology have varying degrees of attractiveness based on short and long term economic factors such as the level of housing starts, the general health of the economy, and the number and location of competing producers within a given market segment.

   The specific criteria used included:

   - No single business/technology, in a single development, should consume more than 5percent of the total market for which it is competing. *(Scoring: -1, 0, or 1).*
   - If the business/technology produces a commodity product that is not sold under a long-term “take or pay” contract, the projected economics of the business/technology must be such that it can be shown to be profitable with the lowest commodity prices in each of the last 5 years. *(Scoring: -1, 0, or 1).*

- If the business/technology is receiving, through government mandate, special tax credits, allowances, etc., the special circumstances must be shown to continue for the life of the project debt. *(Scoring: -1, 0, or 1).*
- The business/technology must be able to demonstrate that there is a defined and supportable market segment for the product, with potential demand from multiple customers. *(Scoring: -1, 0, or 1).*
- A general rating of the degree of “market attractiveness” based on the project team’s expert opinion. This category was weighted more heavily than the other categories because the project team believes that identifying technologies with clear documentation of favorable market outlooks is critically important in identifying the most promising technologies. *(Scoring: 0 to 10).*

3. **Scale of Operation**: An inherent range exists in the size (in terms of raw material usage) of each business associated with the various technologies identified. Since one of the objectives of the study is to identify business opportunities that can meaningfully increase the pace and scale of restoration efforts, the technologies that are larger scale scored higher in the screening process.

   The specific criteria used included:

   - The business/technology must be of a scale such that it can be shown that a single installation is matched to the output/needs of the average California sawmill for treatment of a single by-product stream (e.g., chips, bark, shavings, sawdust, slash). *(Scoring: -1, 0, or 1).* For example, a sawmill producing 100 million board feet of lumber per year will produce about 50,000 bone dry tons of chips, sawdust, shavings, and bark combined annually. A technology that can utilize raw material on that scale was scored as meeting this criteria.
   - If this technology is implemented or expanded in California it will have a measurable impact on the ability to carry out small diameter forest management treatments. (Scoring: 0 to 10; where a score of 0 = a business that in a single installation uses less than 10,000 green tons of material per year, 2 = 10,000 to 25,000, 4 = 25,000 to 75,000, 6 = 75,000 to 150,000, 8 = 150,000 to 250,000, and 10 = greater than 250,000).

4. **Other/Miscellaneous:** To achieve better differentiation in the screening results, the project team elected to add two additional criterions which fall under an other/miscellaneous category.

   The specific criteria used included:

   - Degree of innovativeness – one of the overarching objectives of the study was to identify innovative business opportunities. Therefore, the project team included as a criterion the “degree of innovativeness” – not necessarily in terms of innovativeness of the technology, but rather for factors/features like application of a technology in a unique region or an innovative source for securing raw material, etc. *(Scoring: 0 to 2, with 2 being “most innovative”).*

- Raw material or infrastructure constraint specific to California – some of the technologies considered may appear attractive from a number of perspectives, but because of circumstances specific/unique to California, the technologies received a lower score. Examples include lack of supporting infrastructure such as rail or deep water ports, etc., or excessive regulatory hurdles. *(Scoring: 0 to10, with 0 having the highest constraints and 10 having no constraints).*

4.3 SCREENING PROCESS

The project team developed a series of 'one-page' descriptions for each technology. The objective of each one-pager was to assemble information about each technology that would help inform the project team in completing the screening process. The one page technology descriptions are included in **Appendix 1**.

4.3.1 Screening Results

Using the completed one-page descriptions as reference documents, the project team gathered as a group a number of times to score the various technologies using the screening criteria described in **Section 4.2.** As indicated by gathering a number of times, the process was iterative. In other words, the project team initially scored each of the technologies and then during subsequent meetings made revisions to the scores and to the screening tool before arriving at the results shown below. The result off this effort was a Technology Screening Matrix. It has the full detail of all the scores for each criterion for each technology. The Technology Screen Matrix is included as **Appendix 2**. A condensed version showing the scores of the highest rated technologies is shown in **Table 4.2**.

Table 4.2 – Top Rated Technologies

Technology	Screening Process Score
Cross Laminated Timber (CLT)	32
Veneer – Plywood/Laminated Veneer Lumber (LVL)	30
Small Biomass Combined Heat and Power (CHP)	29
Oriented Strand Board (OSB)	28
Animal Bedding	27
Post and Pole	27
Wooden I-joists	26
Glue Laminated (Glulam) Beams	26
Decorative Bark/Mulch/Compost	26
Firewood	26

Finally, in addition to independently completing the screening process, the project team gathered feedback on the preliminary results from a variety of stakeholders in California. This included: individual meetings with members of the forest products industry within the state, from distinct geographic regions, and gathering feedback from the project's steering committee, which includes representatives of:

- California Forestry Association
- Cal Fire – Department of Forestry and Fire Protection
- National Forest Foundation
- University of California
- U.S. Forest Service

4.3.2 Forest Industry Stakeholder Workshop

The project team also convened a one-day forest industry stakeholder workshop on the UC Davis campus. The attendees were comprised of forestry and forest products stakeholders in California. More than 20 people attended the workshop, including representatives of sawmills, industrial forest landowners, veneer/plywood/LVL manufacturers, the biomass heat and power industry, Woodworks – a trade association aimed at promoting the use of wood, and the wood landscape, bedding, mulch, and compost industry. Also attending were members of the project team, the steering committee, and faculty from the UC Davis business school.

The format of the workshop consisted of the project team presenting background about the project and its objectives, reporting on the methodology used to screen the technologies, and reporting on the results of the screening process. The workshop attendees were then led through a facilitated discussion that allowed them to provide feedback about the results and discuss the pros and cons of each of the technologies judged by the project team to have a high likelihood of being viable businesses. The feedback from workshop attendees on the highest scoring business opportunities is summarized in Chapter 5. The feedback for the remaining business opportunities discussed at the forest stakeholder workshop is summarized in **Appendix 3**.

4.3.3 Raw Material Supply

Raw material supply and delivered cost are perhaps the most important aspects to the success of any forest products business. However, up to this point these issues have not been considered in the Project Team's analysis. This is because many of the technologies analyzed use different raw material inputs (e.g., differing species requirements, different sizes, and different forms of wood fiber – logs, pulpwood, chips, hog fuel, etc.) Therefore, in this project, technologies that have been proven commercially, appear to have good markets, and are reasonably large scale were identified first. The following supply analysis can be focused on the availability and cost for the specific type of material needed and on the region where such a business would logically make the most sense. This methodology eliminates the chance of a generic supply study that could be focused on the wrong type of raw material. Mason Bruce and Girard (MB&G), a forestry and natural resources consulting firm based in Portland, Oregon and part of the consulting team for this project, will complete a supply analysis as an intermediate step between the technology screening and the detailed feasibility analysis and business planning.

CHAPTER 5 – OPPORTUNITIES SELECTED FOR DETAILED REVIEW

This chapter provides a description of the four business technologies selected for detailed review. Information for each technology includes a general description of the technology/opportunity, its pros and cons, and identification of the topics that need further analysis for the specific technology. Also included is the rationale underlying the selection of each technology.

5.1 CROSS LAMINATED TIMBER (CLT)

5.1.1 CLT General Description

CLT panels were first developed in Austria and Germany during the early 1990's through a joint research effort between industry and academia. The panels are referred to as a mass timber building material that offers a wood-based solution as an alternative to some applications that have traditionally used concrete, masonry and steel (see **Figure 5.1** for an example of a CLT panel). After a few years of relatively slow market development during which product approvals were secured and marketing and distribution channels were developed, construction in CLT increased significantly in the early 2000's in Europe among both non-residential and residential applications.

More recently, in the United States interest developed among architects, engineers, and the forest products industry for expanding the use of CLT in North America. For example, the International Building Code for 2015 was written to explicitly recognize mass timber systems (including CLT) for multi-family, educational, commercial, industrial, retail, public, recreational, and institutional buildings. While it is expected to take some time for the IBC recognition to trickle down to state and local building codes, this is significant because it is expected to eventually pave the way to wider adoption of CLT. If CLT use were widely adopted it would create a significant new market for softwood dimensional lumber. At the current time there are only 3 CLT manufacturers operating in North America: Nordic Structures in Quebec, QC, StructureLam in Penticton, BC, and SmartLam in Columbia Falls, MT. The SmartLam plant is currently manufacturing CLT panels for non-structural applications (e.g., rig and crane mats used in oil and gas drilling), but they are currently planning to expand their manufacturing plant to produce CLT panels for use in structural applications. In addition, D.R. Johnson of Riddle, Oregon, has announced plans to add structural CLT panel production to their existing sawmill and glulam beam manufacturing facilities.

Figure 5.1 – Example CLT panel

5.1.2 Positive Aspects of CLT

As can be seen in **Figure 5.1**, CLT is somewhat analogous to plywood since it is a panel made up of different layers (lamella) where the wood grain in each lamella is oriented perpendicular to the adjacent layers. Adhesive is typically applied to the surfaces between layers, but not as commonly to the edge surfaces between the boards within a layer. After the adhesive has set the resulting mass timber panel is much more dimensionally stable than solid sawn lumber. This is because as the moisture in the wood changes it tends to shrink and swell very little in the longitudinal axis. Thus, the more problematic tangential and radial shrinking and swelling in wood is limited because those axes are restricted from changing dimension by the adjacent longitudinal axis. The panels are generally constructed in an odd number of layers ranging between 3 and 9 layers. Polyurethane adhesives are used in the manufacturing process. Such adhesives do not require heat to set. Thus, process heat is generally not needed in CLT manufacturing (provided the lumber has already been dried to the required specifications).

Aside from enhanced dimension stability (relative to most other wood-based materials), the advantages of CLT are numerous. First, California could be a key market for CLT since testing of buildings up to 7 stories tall made from CLT have shown that they can withstand earthquakes very well.[12] Second, CLT panels are typically prefinished to very precise final dimensions, including cut-outs for windows, doors, and service channels for utilities such as electrical, plumbing, heating, cooling, etc. The prefinished panels can be erected at the job site very quickly and with very little labor relative to buildings made of concrete and steel.[13] In addition, the panels are light weight relative to steel or concrete. This means that smaller cranes can be used to lift panels higher and the building's foundations do not need to be as large as a similar building constructed from steel or concrete. It has been estimated that the cost of constructing

[12] Seismic Behavior of Multistory Cross Laminated Timber Buildings. Ario Ceccotti. 2010. Presentation at UNECE-SWST International Convention. Accessed at: http://www.swst.org/meetings/AM10/ppts/Ceccotti.pdf.
[13] CLT Handbook, U.S. Edition. 2013. FPInnovations and Binational Softwood Lumber Council.

a building's shell could be 10 to 50 percent less expensive than using concrete and steel.[14] Thus, in addition to the cost savings from the preceding factors, the use of CLT allows the lighter buildings to be constructed on soil types that otherwise might not support heavier steel and concrete buildings.[14]

CLT buildings have enhanced fire performance. This is because heavy timbers tend to char on the outside when subjected to fire yet retain 85 to 90 percent of their strength during the critical time period for evacuating a building in the event of fire.[15] According to FPInnovations, all of the preceding advantages will translate into the use of 0.8 to 2.4 billion board feet of lumber per year in the United States by 2015 for manufacturing CLT, which will be used to construct building shells estimated to have a value of $1.5 to $4.5 billion per year.[16]

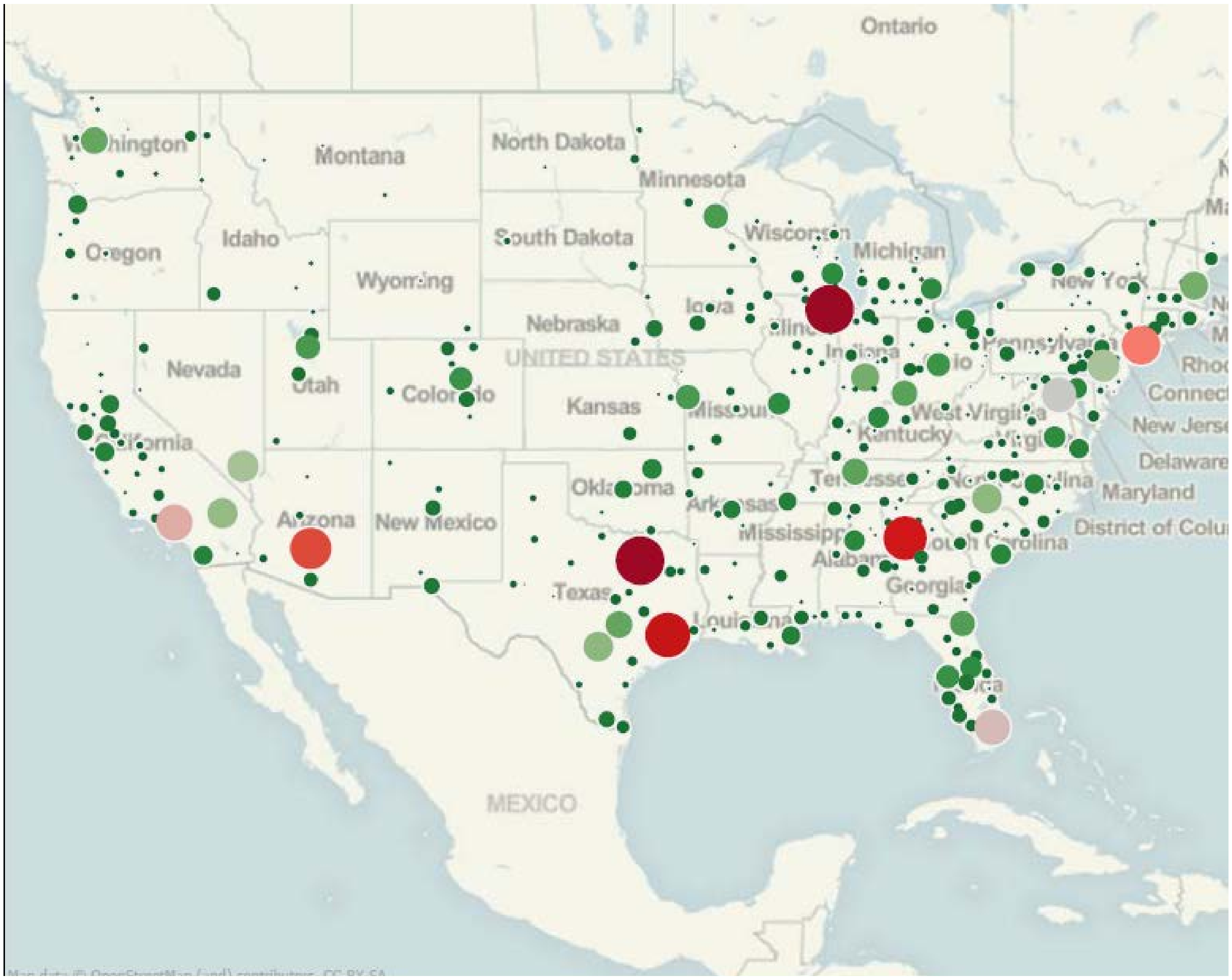
A very recent development occurred during council hearings for adoption of language in the 2018 International Building Code. Concrete industry interests successfully lobbied the council to include preliminary language that would not allow the 2018 version of the IBC to increase the height threshold for Type IV (heavy timber) buildings to nine stories. The council will vote on whether or not to accept the preliminary language later in 2015.[17]

Specific to California, the forest industry stakeholder workshop attendees identified the following advantages to developing CLT manufacturing capacity in California:

- *Close to large market in California* – Relative to existing CLT manufacturers in other states/provinces, a CLT plant in CA would enjoy lower transportation costs to what is expected to be a large market in California (**Figure 5.2**)

[14] The Value Proposition for Cross Laminated Timber. 2011. FPInnovations. Accessed at: http://www.fpac.ca/publications/Value-CLT-2011%20NABC%20anaylisfinal.pdf.
[15] Mass Timber and Fire Performance. ReThinkWood. Accessed at: http://www.rethinkwood.com/masstimber/mass-timber-and-fire-performance.
[16] Cross Laminated Timber: a Primer. 2010. Pablo Crespell. FPInnovations. Accessed at: https://fpinnovations.ca/media/publications/Documents/clt-primer.pdf.
[17] Concrete Interests Ensure Code Provisions for Taller Wood Buildings Hit Brick Wall. Accessed at: http://www.concreteproducts.com/news/8980-concrete-interests-ensure-code-provisions-for-taller-wood-buildings-hit-brick-wall.html#.VWY4wM9VhBd

Figure 5.2 – Key U.S. Construction Markets for CLT



Source: FP Innovations

- *CLT could open closed timber markets* – Increased demand for lumber could lead to re-opening sawmills, which in turn could lead to increased demand for timber.
- *CLT will broaden lumber market* – CLT manufacturing in California would provide a new market to existing dimensional lumber producers in California.
- *Carbon sequestration* – Wood contains embodied carbon. When wood is placed in use in buildings it sequesters carbon for the life of the building. This effect is amplified when wood is replacing concrete or steel as a building material, which is often the case when CLT is used.
- *Displacement of steel and concrete* – Use of steel and concrete as building materials is associated with the emission of large volumes of greenhouse gases. CLT, in contrast, would be associated with a much lower level of greenhouse gas emissions.
- *Robust fiber supply* – The existing softwood lumber manufacturers in California are capable of providing significant quantities of raw material to a CLT manufacturing facility.

- *CLT export market* – There potentially may be opportunities to export CLT panels to other U.S. states and internationally
- *Modest capital requirement* – Development of a CLT manufacturing facility represents a relatively small capital investment (roughly estimated to be about $15 to $30 million), depending on the scale of the operation.
- *No stacks* – Environmental permitting of new businesses in California is difficult if the business emits particulates or pollutants into the atmosphere via a "smoke stack". CLT manufacturing does not directly produce such emissions and therefore would be expected to face fewer obstacles in obtaining the required operational permits.
- *No heat source needed* – Assuming that the lumber used in CLT manufacturing has already been dried to the specified moisture contents, no process heat is required in the CLT manufacturing process.

5.1.3 Negative Aspects of CLT

The forest industry stakeholder workshop attendees identified the following potential disadvantages to developing CLT manufacturing capacity in California:

- *Possibility for lack of supply of raw material* – The currently accepted species for CLT manufacturing include Douglas fir/Larch and Spruce/Pine/Fir (SPF). In addition, only a limited amount of 2"x4" material can be used, and only in the interior plies. Thus, depending on the lumber species and size mix produced in some regions, there may be supply limitations.
- *Policy restrictions drive up transaction costs* – As a general conclusion, workshop attendees felt the regulatory environment in California leads to higher transaction costs than might be incurred by similar operations in other states.
- *Possibility of extra drying required* – CLT manufacturing requires lumber dried to 12 percent moisture content (+/- 3 percent). The current practice in much of California's lumber industry is to dry dimensional lumber to 19 percent moisture content since that is what is required by other users. Thus, there may be limited ability (at least initially) of existing manufacturers to complete extra drying and to achieve the tighter moisture tolerances required by CLT manufacturers.
- *CLT is not a commodity product, but a customized panel* – At this point in the development of the CLT industry, the approach has generally been to design the CLT panels for each building as one-off projects. This approach requires someone (e.g., the panel manufacturer, the developer, the building owner, etc.) to pay for the cost of designers and engineers to specify the strength characteristics needed from the CLT panels to be used and to locate all cutouts, fastener holes, etc. It will be important for CLT manufacturers to have staff with building material design and specification knowledge and experience.
- *Little impact on timber consumed* – Since CLT manufacturing requires lumber as a raw material as opposed to logs, there is no direct impact on the volume of timber

consumed. However, if CLT were to develop into a preferred construction material, the indirect demand from CLT manufacturers would translate into increased demand for timber from lumber producers.

5.1.4 Topics for Further CLT Analysis

The following is a list of key topics that require further analysis in the project team's assessment of CLT manufacturing feasibility and business planning.

- *Market Size and Market Value* – Since the CLT industry is in the early stages of development, there are many unknowns about the size of the market, the value of the market, and how quickly the market will develop to support CLT manufacturing in North America.
- *Competing Manufacturers* – FPInnovations, a large, private non-profit Canadian forest research center, is actively engaged in identifying, researching, and assisting in the development of innovative solutions to forest products industry challenges. CLT has been a focus area for FPInnovations. Thus, CLT manufacturers in Canada may be better positioned to endure developmental hurdles during the early stages of the CLT industry.
- *Barriers at Construction Management Level* – Since CLT is a new building technology it is unknown what barriers might present themselves in terms of building design and construction when pursuing CLT projects.
- *Environmental Attributes of CLT* – A recent trend in construction is the use of the LEED System for certifying a building's compliance to energy and environmental standards. Wood as a building material is often viewed as not "getting enough" credit in the LEED scoring system. It is not clear if or how this will change with the advent of CLT panel use in building construction.
- *Codes and Standards Development in CA/US* – The current building height limit for wood structures is 85 feet. However, designers and architects have developed plans for wooden buildings that would be much taller. At this point it is not clear if building officials will refine high rise codes and standards for buildings made out of wood.

5.2 ORIENTED STRAND BOARD (OSB)

5.2.1 OSB General Description

OSB is an engineered wood panel comprised of strands that are bonded together with resin. The panels are produced in a variety of thicknesses[18] ranging between ¼" and ¾". It is produced in a variety of lengths and widths, but by far the most common are 4' wide by 8' long. The panels are most commonly used as sheathing in building wall and roof systems, but are also

[18] A convention in the OSB industry is to account for panels produced to varying thicknesses by expressing square feet of panel production on a 3/8" thick basis. For example, 1,000 square feet of panels that are ¾" thick would be expressed as 2,000 square feet on a 3/8" basis.

used as flooring and in various industrial/specialty applications. **Figure 5.3** displays an example of a finished OSB panel.

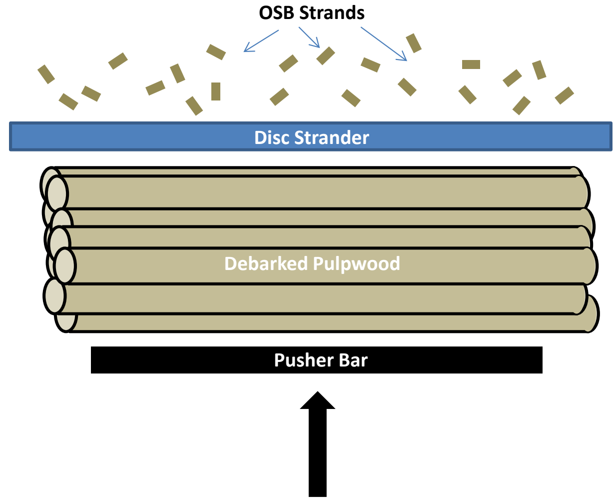
Figure 5.3 – Sample OSB Panel

The manufacturing process typically starts with pulpwood (small diameter logs) that are debarked and then stranded. Stranding is the process of converting the logs into strands that are about 0.03” thick and uniform in thickness along their entire length. Strands also have a uniform width to length ratio – about 6” long by 1” to 2” wide. The specialized machines developed for creating pieces of wood with these dimensions are called stranders. The main part of a strander is an 8 foot diameter spinning disc with about 50 knives radiating out from the center of the disc like spokes in a wheel. Strands are cut parallel to the long axis of the incoming roundwood feedstock in order to achieve panels with the desired strength properties (**Figure 5.4**).

As shown in the top view portion of the figure, the wood fiber is oriented with the grain parallel to the plane of the spinning disc. The material is then pushed into the spinning disc and the knives cut the feedstock into flakes. It is common that about 90 to 95 percent of the incoming roundwood volume is converted to strands of acceptable size. The balance of the volume is fines or strands that are too small to be used for OSB manufacturing. Stranding is most effective when the feedstock is green (i.e., at least 30 percent moisture content, wet basis). Dry feedstock tends to result in strands with an excessively high percent of fines.

Figure 5.4 – Simplified OSB Stranding Machine Diagram

Side View of Disc Strander



Top View of Disc Strander

After the strands are produced, they are dried to about 2 to 6 percent moisture content. This is generally accomplished in a rotary drier. After drying, the strands are blended and formed. Blending involves the addition of resin and wax to the strands. Wax is added to increase the panel's water repellency and it usually comprises less than 1 to 2 percent of the panel's weight. Resin is added so that the strands will bond together. Forming is the process of placing the blended strands in the form of a mat. This is accomplished by having the blended strands drop from forming heads onto a moving mat. Forming heads orient the strands so that their longest dimension is parallel to the other strands. Forming also involves the development of distinct layers across the thickness of the panel. The two outer (surface) layers of a panel have the long strands oriented in the same direction. The inner layer has the long axis of the strands oriented perpendicular to the outer layers.

After stranding, drying, blending, and forming, the resulting mat is placed in a hot press. The presses used in the industry are multi-opening, meaning that a number of panels can be pressed in each cycle. The presses also tend to be much larger than a single panel in order to maximize the production of the plant. The final step in the process is trimming the panels to size.

5.2.2 Positive Aspects of OSB

The vast majority of the global OSB production capacity is in North America. In 2005, global OSB production peaked at 25 billion square feet (3/8" basis). Production then declined due to the economic downturn. However, as the economy has recovered, production has begun increasing. Forest Economic Advisors (FEA) estimates that global production in 2015 will be 21 billion square feet (3/8" basis). California, generally a leading state for home construction, represents a significant market for OSB.

5.2.2.1 Transportation Cost Savings

Importantly for the CAWBIOM study, no existing OSB producers are near California's large building materials markets in the Bay Area, Sacramento, and Los Angeles. The closest OSB plant, located in south central British Columbia, is about 1,100 miles from Sacramento. The next closest plants are located in East Texas and are about 1,800 to 1,900 miles from Sacramento and about 1,600 miles from Los Angeles.

BECK reviewed published OSB prices[19] between 2004 and 2014 for 7/16" OSB panels. Prices for that product are reported on f.o.b. mill basis in British Columbia and Eastern Texas and on delivered price basis in Sacramento, California. Therefore, the difference in those prices is the apparent transportation cost.

As shown in **Table 5.1**, the average apparent transportation cost between British Columbia and Sacramento during the stated time period is $45/MSF (3/8" basis). The apparent transportation cost from Texas to Sacramento is $38/MSF (3/8" basis). Note, however, that an OSB plant in Northern California would not be able to capture the entire transportation cost savings for material coming from British Columbia or East Texas since California would also have to deliver its product to market. BECK estimates that a Northern California OSB plant's transportation cost would be about $15/MSF (3/8" basis) for product shipped to Southern California. It would be less for product shipped to less distant California market regions (e.g., the Bay Area, Sacramento, etc.) Therefore, BECK concludes that, at a minimum, an OSB plant located in California would have a $23/MSF (3/8" basis) transportation cost advantage over the Texas producers and a $30/MSF (3/8" basis) advantage over British Columbia producers. This is a significant advantage and makes the concept of OSB manufacturing worthy of consideration.

[19] Random Lengths. The Weekly Report on North American Forest Products Markets. www.randomlengths.com

Table 5.1 – Apparent OSB Transportation Costs to California (All Values $/MSF (3/8" Basis))

Year	OSB Price Delivered to Sacramento	OSB Price f.o.b. East Texas	OSB Price f.o.b. British Columbia	Apparent OSB Transportation Cost TX to SAC	Apparent OSB Transportation Cost BC to SAC
2004	391	361	355	30	36
2005	343	323	304	20	39
2006	232	215	196	17	36
2007	192	153	154	39	38
2008	199	161	155	38	44
2009	187	161	145	26	42
2010	261	210	214	51	47
2011	212	172	154	40	58
2012	310	259	268	51	42
2013	351	294	299	57	52
2014	258	208	195	50	63
Average	**267**	**229**	**222**	**38**	**45**

5.2.2.2 Market for Sawmill Residuals

Another potentially positive aspect of developing an OSB plant in Northern California is that the OSB plant could provide sawmills with a much needed market for sawmilling by-products. For that advantage to become a reality, it would require the sawmills to divert their downfall materials to an OSB disc strander as an alternate option to the current practice of producing pulp chips from downfall. This would be a fundamental change in the current operating practices of the industry, and the concept is new and untested in California. However, it has been used successfully at the Martco OSB plant in Le Moyen, Louisiana, which was co-located with a sawmill.

Figure 5.5 shows sawmill slabs and edgings being collected and readied for stranding. As shown in the figure, the downfall material from sawmills can be collected and oriented so that the grain of the material is generally parallel for feeding into a disc strander – a process similar to that typically used for roundwood feedstock. Further research into the feasibility of using this concept in California and the proportion of an OSB plant's total raw material requirement that could be sourced from sawmill downfall will be key components of the detailed feasibility analysis.

Figure 5.5 – Sawmill Downfall (Slabs and Edgings) Staged for Feeding into an OSB Disc Strander

In addition to the positive aspects of OSB production already described, the forest stakeholder workshop attendees identified the following advantages to developing CLT manufacturing capacity in California:

- *Large scale/Large volume of raw materials input* – A typical OSB plant in North America uses 700,000 to 800,000 green tons of raw material per year. This translates into roughly 26.5 million cubic feet, about 750,000 cubic meters, or about 350,000 bone dry tons per year. It is not uncommon for overstocked forest stands in the Sierras to contain over 100 bone dry tons of biomass per acre. For example, in a recent biomass heat and power fuel supply study completed by The Beck Group, about 13 percent of the total timberland in the supply area near Oroville, California was in an overstocked condition and contained a total of volume of 111 bone dry tons of biomass per acre.[20] The amount of material recovered per acre would vary depending on the treatment specifications, but regardless an OSB plant would create a large market for this material and thereby allow for more cost effective forest management activities (e.g., thinning and wildfire hazard reduction) across a large landscape.
- *Can use a range of raw materials* – In addition to the concept of using sawmill downfall as a raw material, an OSB plant can use a range of species and sizes in roundwood form

[20] The Beck Group. Biomass Heat and Feasibility Study. Mooretown, Rancheria, Mooretown, California.

as raw material. Thus, there would be relatively few restrictions about the type of material the plant would accept as feedstock.

- *Market Related* – OSB manufacturing in California shows strong potential from a market perspective because it is used extensively in residential building applications due to its being an inexpensive substitute for plywood, which had historically been used in structural housing applications. As shown in **Table 5.2**, California represents a significant portion of the total U.S. Housing market each year.

Table 5.2 – California Housing Starts as a Percentage of Total U.S. Housing Starts

Year	California Single Family Units	California Multi Family Units	California Total Units	All U.S. Units	California as a Percent of U.S. Total Units
2000	105,595	42,945	148,540	1,592,000	9.3
2001	106,902	41,855	148,757	1,636,000	9.1
2002	123,865	43,896	167,761	1,747,000	9.6
2003	138,762	56,920	195,682	1,889,000	10.4
2004	151,417	61,543	212,960	2,070,000	10.3
2005	155,322	53,650	208,972	2,155,000	9.7
2006	108,021	56,259	164,280	1,838,000	8.9
2007	68,409	44,625	113,034	1,398,000	8.1
2008	33,050	31,912	64,962	905,000	7.2
2009	25,046	11,163	36,209	583,000	6.2
2010	25,526	19,236	44,762	604,000	7.4
2011	21,631	25,705	47,336	624,000	7.6
2012	27,558	32,080	59,638	829,000	7.2
2013	36,878	48,432	85,310	991,000	8.6

5.2.3 Negative Aspects of OSB

The following issues were identified by the forest industry stakeholder workshop attendees as being potentially negative aspects of siting an OSB manufacturing facility in California.

- *Some idle capacity* – According to Forest Economic Advisors, the effective capacity of North America's OSB industry will increase in 2015 to 24.7 billion square feet (3/8" basis). The restarting of idled mills is expected to increase the North American industry's capacity to 25.3 billion square feet in 2016. FEA expects plants to operate at about 82 percent of effective capacity in 2015 and climb to close to 90 percent in 2016. However, as described previously, the demand to capacity ratio would be expected to be less of an issue for a California OSB producer since it would be isolated geographically from other producers and therefore less affected by competition from other manufacturers.

- *Capital intensive-Large capital investment required to start operations* – Constructing an OSB plant is a large, capital intensive project that, in the project team's opinion, would have to be undertaken by a firm who is already in the OSB business because those firms already have the plant operating experience and the market distribution systems in place. Nearly 10 years ago J.M. Huber constructed a greenfield OSB plant in Georgia for a price reported to be in excess of $200 million. Similarly, in 2004, Louisiana Pacific constructed a greenfield facility in the mid-2000's in Clarke County Alabama for a reported $250 million dollars. Another example is Tolko, who in 2008 constructed a plant capable of producing 825 million square feet per year (3/8" basis) in Slave Lake, Alberta for a reported $250 million dollars.
- *Difficult to source enough raw materials to keep operations steady* – As previously described, an OSB plant consumes significant volumes of raw material annually (approximately 700,000 to 800,000 green tons per year). This means siting the facility will be a critically important consideration. The project team anticipates the required raw material coming from a combination of supply sources, including sawmill downfall, small diameter roundwood sourced from currently unutilized tops of sawlogs, and small diameter roundwood harvested specifically for an OSB facility. Determining the proportion of the feedstock requirement from each of these sources and the associated delivered cost will be key areas of analysis in the feasibility and business planning work.

5.2.4 Topics for Further OSB Analysis

The following is a list of key topics that require further analysis in the project team's assessment of an OSB plant feasibility and business planning.

- *Permitting risks* – The California Environmental Quality Act (CEQA) is an environmental law designed to guide the issuance of permits and approve projects. It applies to all discretionary projects proposed to be conducted or approved by a California public agency, including private projects requiring discretionary government approval. Thus, any private corporation proposing development of a forest products conversion facility (including OSB) would have to go through a CEQA process, which would include development of an Environmental Impact Report (EIR) that would identify and publicly disclose significant environmental impacts associated with the project and identify potential mitigation measures for the acknowledged environmental impacts. Also included in the process is the opportunity for comments on the proposed project from public agencies and the general public. Given the scale and complexity of OSB manufacturing, the CEQA process for an OSB facility will be arduous and could potentially lead to the project not being developed because the mitigation options required to gain approval would be too costly.
- *Transportation costs of raw materials* – Another potential issue related to raw material supply for an OSB facility is the size of the procurement area required to gather the raw material. In other words, while there may be enough raw material available, the size of

the area needed to procure the material may be very large. Should this be the case, the cost of transporting raw material from the outer edges of the procurement zone may be cost prohibitive. Another issue related to transportation costs for raw materials relates to strands produced from sawmill downfall. If the stranding is completed at sawmills, it has been reported that the expansion factor in going from solid wood to strands is 14 to 1. Thus, the strands are very fluffy, and it will be difficult for trucks loaded with strands to reach their maximum legal weight payload. If this is the case, it will increase the delivered cost of those materials. This issue will be researched in greater detail in the feasibility and planning phase.

5.3 SMALL SCALE BIOMASS WITH CO-LOCATED BUSINESS(ES)

5.3.1 Small Scale Biomass General Description

The term Small Scale Biomass refers to a range of technologies for utilizing a range of woody biomass types to produce heat, power, or both, and in some cases, by-products. Thus, small scale biomass can take on many forms depending on the specifics of the technology employed, the type of fuel used, and how the resulting energy is utilized. The project team is not aware of any well-defined criteria for classifying a biomass application as small. However, for the purposes of this study, the term small scale will be used to refer to projects equal to or less than 3 megawatts (MW) in size.

Revenue is generated in biomass projects by selling heat, electrical power, or both. As a general rule, a project developer is best served by selling power to the grid as renewable power instead of producing the power for self-consumption, thus capturing the green premium. Heat can only be sold if there is a nearby business (process heat) or building (thermal energy) that has a need for the heat. In some cases, revenue is also generated by selling renewable energy credits or carbon credits. Offsetting those revenues are the capital costs for developing a biomass facility, the operating and maintenance costs associated with the facility, and the cost of the biomass fuel.

Generally, there are clear economies of scale associated with biomass projects. This is because it takes almost the same amount of labor to operate a relatively large biomass plant as it does to operate a relatively small plant. Thus, the smaller plant (with less capacity to produce power, and therefore revenue) has labor costs that comprise a much higher percentage of its revenue as compared to a larger scale plant. In addition, the capital expense per unit of output drops considerably on larger projects versus smaller projects. With smaller plants, this affects project economics negatively because they have relatively high capital costs per unit of output and limited capacity to produce power/revenue to recover those capital costs. As a result, it takes a rare set of circumstances for small scale projects to be economically viable.

5.3.1.1 <u>Co-Located Businesses</u>

One option for enhancing the economic viability of small scale biomass projects is to have co-located business(es) at the biomass site that are designed to utilize various forms of small diameter forest-derived material. Those businesses may have process heat needs, which would provide a market for the heat produced at a biomass plant. Those businesses may create by-products that can be used as fuel at the facility. It is not known at this point whether such by-products would meet the restrictions placed on fuel sources in the SB 1122 program.

Concerning the economic structure of those businesses, it might be such that it creates a higher value from the flow of biomass material in the region and thus subsidizes the delivered cost of fuel for the small scale biomass facility. Therefore, in the second phase of this project, the project team will investigate the feasibility of developing a small scale biomass facility with one (or more) co-located businesses. The types of co-located businesses considered will include three that scored high in this study's technology screening process: 1) post and pole manufacturing; 2) animal bedding (manufactured directly from roundwood); and 3) firewood production.

5.3.1.2 California Senate Bill 1122

California, through the provisions of SB 1122, will likely create a scenario such that small scale biomass makes economic sense. The bill requires California's investor owned utilities to purchase 50 MW of power from the by-products of sustainable forest management, with no single project in the program being larger than 3 MW. The legislation is being implemented by the California Public Utilities Commission (CPUC). The CPUC, through the help of a consultant (Black and Veatch)[21], projected the Levelized Cost of Electricity (LCOE) from 3 MW forest biomass projects. As shown in **Table 5.3,** the costs are estimated to range between $148/MWH and $281/MWH depending on assumptions about capital costs ($/kilowatt of capacity), non-fuel operating costs ($/KW per year), and fuel costs ($/bone dry ton).

Table 5.3 – Small Scale Forest Biomass Projects Levelized Cost of Electricity (LCOE)

	Low Estimate	Medium Estimate	High Estimate
Capital Cost ($/KW)	5,000	6,000	7,500
Non-fuel Operating Cost ($/KW/year)	347	553	590
Size (MW)	3	3	3
Feedstock Cost ($/dry ton)	30	45	60
LCOE ($/MWH)	**148**	**219**	**281**

[21] Small-Scale Bioenergy: Resource Potential, Costs, and Feed-in Tariff Implementation Assessment. Black and Veatch. October 2013. Accessed at: http://www.cpuc.ca.gov/NR/rdonlyres/F95D0DD7-DEB3-4725-81B1-A24BAA8AE245/0/CPUCBioenergyReport10_31.pdf

The financial assumptions used in the Black and Veatch model were that the facility would be owned by a private taxpaying entity and that no tax advantages, credits, or low cost financing would be available. Some of the key metrics in the model were:

- Debt/Equity ratio of 60/40
- Debt rate of 7 percent for 15 years
- Equity Cost of 12 percent
- Depreciation using 7 year MACRS (Modified Accelerated Cost Recovery System) on all capital costs
- Federal/State combined tax rate of 40 percent
- 2 percent annual inflation on operating, maintenance, and fuel costs
- Annual capacity factor of 85 percent
- Heat rate (mid-range) of 16,500 BTU/KWH
- 3MW net generating capacity
- Gasification technology combined with three 1MW internal combustion engines
- No value given for other by-products
- No unusual interconnection issues or costs
- Following startup, no annual capital expenditures
- Project life of 20 years with no terminal value or cost
- 2013 dollars

Some of the projects that are being contemplated utilizing the SB 1122 program are located in economically depressed rural communities, which would make them eligible for New Market Tax Credits (NMTC), and there is typically some government agency financial involvement. Those two factors are mechanisms for lowering debt costs and equity requirements, which were not accounted for in the Black and Veatch study. In addition, some proposed technologies would produce by-products with value, and some would have thermal customers – neither of which was included in the Black & Veatch study. Therefore, the project team estimates that a 3 MW rural project could accept a levelized power purchase agreement (PPA) price of $180 to $200 per MWH for a 15 to 20 year agreement.

Four types of fuel have been determined to be acceptable in the SB 1122 program and that all of the fuel must be from among the four categories and at least 80 percent of the fuel for a given project must be from a single one of the following categories:

- Fire threat reduction projects
- Fire safe clearance activities
- Infrastructure clearance projects
- Other sustainable forest management activities

The CPUC codified the process by which projects enter the SB 1122 program. It is very complex and is described in detail in **Appendix 2**. Several key points, however, are that the project must be in the service territory of one of the Investor Owned Utilities (Southern California Edison – SCE, Pacific Gas & Electric – PG&E, or San Diego Gas & Electric – SDG&E), who are required to comply with the legislation. Since PG&E's service territory is the most heavily forested, that utility is responsible for 47 of the 50 MW requirement. The initial levelized price offered to project developers will be $127.72 per MWH. If there are at least 3 projects in the queue and none of the three can accept a PPA at the price, then the price begins to ratchet upward bimonthly by a predetermined amount and schedule. The price will continue increasing until it reaches a level acceptable to one of the projects. This price adjustment process is called ReMAT (Renewable Market Adjusting Tariff). If the offered price reaches $197/MWH without any takers, it will trigger a price cap investigation by the CPUC.

5.3.1.3 Small Scale Biomass Technologies

There are essentially two main technologies for converting biomass into heat, power, or both. They are *gasification* and *direct combustion*. The following paragraphs briefly describe each.

Gasification of carbonaceous materials, as a technology, has been in use since early last century when it was employed to produce town gas for streetlights. The use of biomass as a feedstock is more recent, but still has been in use providing heat for district heating systems in Europe for nearly two decades.

The process involves heating biomass in the partial or complete absence of oxygen. The result of that process is production of a synthesis gas or syngas composed of primarily CO, H_2 and CO_2, with a small amount of CH_4. The syngas, from biomass feedstocks, also contains tars that must be removed ahead of various downstream processes. The gas could be further refined into chemicals, synthetic natural gas, possibly liquids or simply combusted to produce heat and power.

There are a variety of gasifier designs and equipment suppliers. Designs involve updraft or downdraft flow, various fluidized bed types and even designs that incorporate a bed material such as sand or limestone. The various designs operate at different temperatures to vary the mix of the gas. In addition, the biomass fuel pretreatment and drying requirements vary widely. While this is a relatively advanced technology, work is still needed to demonstrate the performance of gasification systems that utilize fuels resulting from forest management treatments, which tend to have variations in particle size and moisture content, thus hindering overall gasification system performance.

Biomass from forest management treatments has a wide variation within a single load (needles, bark, chips, twigs), and the piece sizes can vary widely because of the nature of the field processing. Also, the moisture content will vary widely by season and by the various pieces in the load. These are not variations that are typically seen in a European district heating application, and so several demonstrations of gasification flexibility with this fuel must be made in the western U.S. before gasification can reasonably stand next to direct combustion as a proven viable technology for small CHP.

In a typical CHP installation, the syngas is treated by cooling/filtration to remove particulate matter, moisture and tars, with the resulting clean gas being combusted in a modified internal combustion engine generator. Heat can be recovered for district hot water systems from the process of cooling the syngas, from the engine cooling system and perhaps even from the engine exhaust stack. A typical European installation may produce the equivalent of 3 MW of thermal energy and 1 MW of electrical energy. The efficiency of the electrical only portion is 25-31 percent when measured on a lower heating value basis (LHV). A properly designed system that can continually utilize all the waste heat can exceed 80 percent in overall efficiency.

Attempts have been made over the years to replace the internal combustion (IC) engine with a gas turbine (GT), which would allow the 25-31 percent conversion efficiency measurement to rise to perhaps 45-50 percent. These many attempts have not been successful, however, as the residual tars and other particulates have destroyed the gas turbine after a short number of hours. This IC engine to GT conversion remains the holy grail of gasification proponents.

Direct combustion, in contrast to gasification, is burning biomass fuel directly to produce heat, power, or both. It is the most common method of converting biomass into energy. Typically, combustion occurs in a chamber where volatile hydrocarbons are formed and burned. From that process, heat energy is released from the combustion chamber in the form of hot flue gases. Those flue gases are directed into a boiler to create steam or hot water. The steam, in turn, can be used to heat a building, supply heat to a manufacturing process, or generate electricity.

Direct combustion systems coupled with a steam turbine typically use one of two designs to combust material. These two basic options are: fixed bed system; and fluidized bed system. Fixed and fluidized refer to the manner in which the material is combusted. The majority of biomass boilers use a fixed bed design in which biomass is burned on a grate containing holes. The holes allow for primary combustion air to be introduced below the grate. The most basic designs simply place the fuel in a pile on the grate. While simple, that method creates inefficient combustion. Therefore, more sophisticated designs use a grate that travels, vibrates, reciprocates, or rotates to spread the fuel uniformly across the grate – thereby, allowing more efficient combustion and automatically removing the residual ash. Key advantages of fixed bed systems are that they are proven, rugged, efficient, reliable, and have a relatively low capital cost and operating costs. In addition, they are available from a variety of vendors. A key disadvantage is that they typically operate at higher temperatures, leading to higher uncontrolled emissions of some pollutants.

A fluidized bed design, in contrast to feeding material to a grate, feeds biomass into a hot bed of suspended, non-combustible particles such as sand. The injection of high velocity air from underneath the bed distributes and suspends the fuel and sand as it is combusted. Fluidized bed designs are distinguished as either bubbling or circulating, depending on whether or not the hot char (the charcoal-like material left after gasification occurs) exits the bed and is captured and returned to the bed. The key advantage of a fluidized design is that the operating temperatures are lower, which reduces NOx emissions and allows for more complete combustion and the fuel flexibility they possess. The key disadvantages are a higher capital cost and higher auxiliary power use.

The energy efficiency of direct combustion is determined by measuring the amount of heat captured in the medium (steam, hot water) relative to the amount of heat stored in the fuel, which is known as the heating value. When direct combustion is used to create steam, which is then used to create power, energy efficiency can range from 20 to 30 percent. However, when there is a use for the waste heat from direct combustion power generation (known as combined heat and power) energy efficiency can be as high as 70 percent.

5.3.2 Positive Aspects of Small Scale Biomass

The forest industry stakeholder workshop attendees identified the following positive aspects of small scale biomass projects in California:

- *Small scale biomass has the ability to produce co-products* – If the technology selected for a small scale biomass project is gasification, then the economics of the project may be enhanced through the production of saleable by-products such as biochar. It should be noted, however, that such markets are not well defined in terms of size and product value. In addition, altering the process to create more biochar would decrease the amount of heat/power produced. Therefore, an analysis of the trade-off between the value of the biochar and the value of the forgone heat/power is needed.
- *Possibility of tapping emerging carbon markets* – California's Global Warming Solutions Act of 2006 (AB 32) established a goal to lower greenhouse gas emissions to 1990 levels by 2020. The incremental goals are achieved through a cap and trade program, and up to this point, these incremental goals have been achieved without dramatically increasing the price of carbon offsets auctioned to greenhouse gas emitters. However, in the future, as the goals become more stringent, it is likely that the value of the carbon offsets will increase substantially. If that occurs, it will enhance the economics of biomass projects because the production of power and by-products from renewable biomass creates carbon offsets that can be sold (provided a protocol is in place) and thereby create an additional revenue stream for biomass projects.
- *Modular units/small footprint* – For direct combustion and gasification technologies, the relatively small size of the projects eases potential development hurdles. This includes smaller project footprints that ease site size requirements. Another potential advantage of smaller projects is potentially less difficulty in obtaining the required environmental permits as they may not rise to the level of Major Sources.
- *More social acceptance, community based, local focus* – Related to the previous advantage, small projects, whose main objective is providing local communities with a means of treating forest health issues and reducing wildfire hazards, and through that process generate rural economic development, are less likely to encounter public resistance to project development.

- *Use high percentage of the energy value of feedstock materials* – Depending on the technology and the specific project thermal host circumstances, it is possible to capture a very high percentage of the energy available from biomass.
- *Guaranteed market* – As previously described, California's SB 1122 legislation provides a guaranteed, long-term market for the power produced by a small scale biomass project.
- *Proven technology* – With respect to direct combustion, the technology has been proven for many decades at thousands of installations. Gasification, on the other hand, does not have the proven track record when the fuel source is biomass derived from forest management activities.
- *Can be conventionally financed* – With respect to direct combustion, small scale biomass projects can be financed using conventional channels.
- *High quality thermal by-product* – Small scale biomass projects produce a high quality thermal by-product that can be useful to a variety of users.
- *Readily available supply leads to economical way of reducing forest fuels/enhancing forest health* – Given the relatively small amount of fuel needed for a 3 MW or less biomass plant and the large volume of forest acres in need of thinning and wildfire prevention treatments, biomass fuel supply is generally not a limiting factor for small scale biomass projects. In addition, the presence of a biomass facility, and the market it creates for biomass material, reduces the cost of forest management treatments since the value of the biomass fuel partially offsets the treatment cost.

5.3.3 Negative Aspects of Small Scale Biomass

The forest industry stakeholder workshop attendees identified the following negative aspects of small scale biomass projects in California:

- *Expensive at small scale* – As previously described, the economic structure of small scale biomass projects is such that the cost of the power produced is multiple times that of other power sources.
- *Unproven technology in the U.S.* – With respect to gasification and the use of forest-derived fuels, the technology does not have a track record of proven use in the United States. As a result, it will be difficult for a gasification project to obtain project financing through conventional channels, or to obtain guarantees of equipment environmental and operational performance.
- *Rigid feedstock requirements regarding size and moisture content* – With respect to gasification, the technology appears to need fuel with little variability in particle size and moisture content in order for the system to operate efficiently.
- *Doesn't consume a lot of material* – While the positive side of not consuming a lot of biomass material means that supply is not a limiting factor, the negative aspect of that fact is that a single small scale biomass plant does not translate into significantly being

able to improve forest health at scale and reduce wildfire hazard across large areas of forest landscape.

- *Requires community consensus* – Despite small scale biomass plants generally meeting less public resistance than large scale projects, there is still a public process that each project may successfully complete, and there is the possibility that a particular community is divided over a small scale project, with the result being that the project does not move forward.
- *Limited viable locations* – for a small scale biomass project to have the best possible economics, it must be located close to forest fuels; have a stable, long-term thermal host; be within the service territory of the three investor owned utilities and have a nearby interconnection to the power grid. That combination of requirements limits the number of locations where small scale biomass projects have a realistic opportunity for siting a viable facility.
- *At the mercy of IOU's* – the SB 1122 law requires the Investor Owned Utilities to procure the power from small scale renewable projects. However, the prices the utilities will have to pay for that power are likely to be several times higher than wholesale power available from other sources. Therefore, it is reasonable to expect that the IOU's will provide a bare minimum amount of assistance to small scale biomass project developers, with the expectation that such a tactic would result in no projects moving forward.

5.3.4 Topics for Further Small Scale Biomass Analysis

The following is a list of key topics that require further analysis in the project team's assessment of small scale biomass projects feasibility and business planning.

- *Permitting Unknowns* – since there have been no previous small scale biomass projects developed under the SB 1122 program, there are unknowns associated with the permitting process. Better understanding the likely required permits, their timelines, and costs will be focus areas in the feasibility and business planning phase of the study. There are, however, larger scale biomass projects that have been permitted previously.
- *Reliance on Carbon Markets/Unknown Demand* – some of the gasification technology business models appear to rely heavily on markets for the by-products (e.g., biochar). Since markets for those products are just developing, a better understanding their extent and product values will be a focus area of the feasibility and business planning phase of the study.
- *High Production Standards in Proposed Power Purchase Agreements* **–** the proposed agreements for the program include a requirement that the project produce 180percent of its contract commitment every two years. This may be too high a hurdle for gasification technologies with previously unproven fuels.

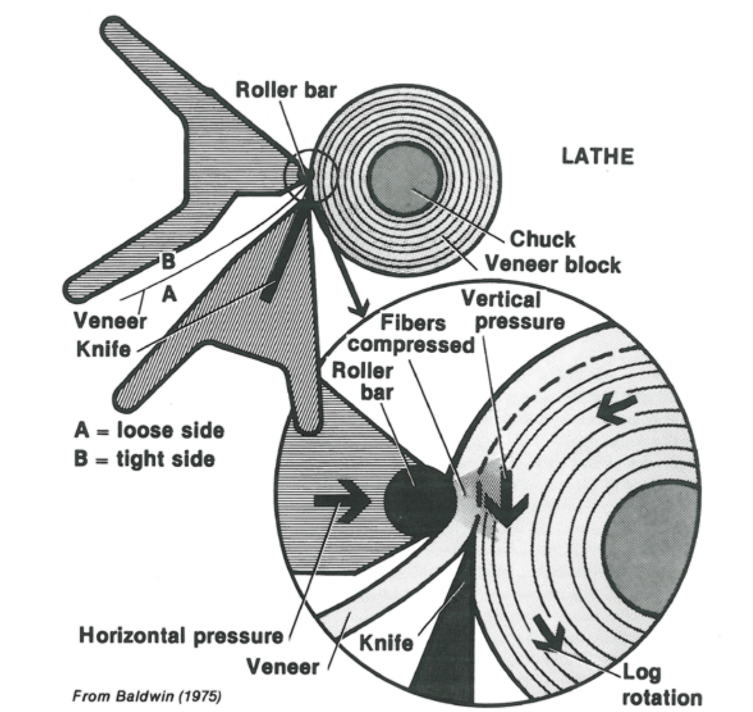
5.4 VENEER – PLYWOOD/LVL

5.4.1 Veneer General Description

Peeling veneer from softwood logs is the first step in producing raw materials for a variety of the technologies being evaluated for this project, including plywood and LVL. Typically, veneer is peeled in thicknesses up to 1/8”. Veneer has been commercially produced from softwood logs for many decades – the technology is well established and mature. The key components of a successful veneer peeling operation are a log resource that is well matched to the desired veneer products, peeling equipment matched to the log resource, and good management.

The veneer manufacturing process for veneer to be used in structural applications involves the use of a rotary lathe and veneer knife. The apparatus produces a continuous ribbon of veneer that is subsequently clipped to recover usable veneer widths. It is a common practice to heat the veneer blocks (log lengths) in vats of hot water or by steaming the blocks prior to peeling. This practice softens the wood and knots, which translates into less power needed for peeling, a smoother veneer surface, and less breakage of the veneer, and therefore, higher recovery. **Figure 5.6** shows a simplified side view cross section of a veneer block and veneer knife on a rotary veneer lathe.[22]

Figure 5.6 – Side View Cross Section of a Veneer Block and Veneer Knife on a Rotary Veneer Lathe



[22] Forest Products and Wood Science. 2007. Jim L. Bowyer et al. Blackwell Publishing, Oxford, UK.

In evaluating opportunities for expanding the use of small diameter timber from California's federal forests, it is important to consider the log supply requirements of a viable veneer peeling operation. Regarding log size, a number of operations in Oregon, Washington, and British Columbia have been successful processing small logs with an average diameter of 8 inches and a minimum diameter of 6 inches. The Timber Products mill in Yreka has installed a lathe dedicated to processing small diameter logs and has developed a successful program for utilizing small logs (6" minimum SED).

Depending on factors such as the taper of the log, this translates to an average tree DBH (diameter at breast height) of approximately 11 inches or larger. Total annual log volume requirements for a new, modern operation would likely be in the range of 15-20 million board feet (Eastside Scribner scale) for a single shift operation, or 30-40 million board feet for a 2 shift operation.

In the U.S. West, Douglas fir is the favored species used for veneer and especially LVL veneer due to superior strength properties. However, other western species such as hemlock, true firs (e.g., white fir, grand fir), and ponderosa pine are commonly peeled. While fire salvaged logs can be peeled for veneer production, they need to be harvested relatively quickly after the fire and not allowed to dry out over the course of many months or years.

In addition to conditioning logs prior to peeling, veneer manufacturing operations need process steam for veneer drying. Therefore, establishment of a veneer plant in conjunction with a biomass power plant would allow for a combined heat and power or cogeneration project. California is currently home to two industrial scale veneer peeling operations, both of which ship the majority of their production to plywood and LVL facilities in Oregon. The addition of plywood manufacturing capacity could add value to small and medium sized timber in California, but only if coupled with additional veneer production.

5.4.1.1 Plywood

Plywood panels (see **Figure 5.7**) are made of individual layers of veneer (plies), with alternating ply having its wood grain oriented at a 90 angle to the adjacent ply. The manufacturing process consists of applying glue to individual veneer plies, laying them up in panel form, and pressing the plies with a heated press. The resulting panel is called plywood. It is common that the outermost ply on each side of a plywood panel has the grain oriented parallel to the long axis of the panel. Therefore, to maintain balance in the panel, it is common that plywood has an odd number of plies. Much like CLT panels described earlier in this chapter, orienting the grain of the adjacent plies at 90 degree angles results in a panel that is much more dimensionally stable than lumber. Most softwood plywood manufacturers use phenol formaldehyde resin. Steam is typically used for heating the plywood presses, so co-location with veneer peeling and/or other users of steam such as a biomass power plant can be beneficial.

Figure 5.7 – Softwood Plywood Panel

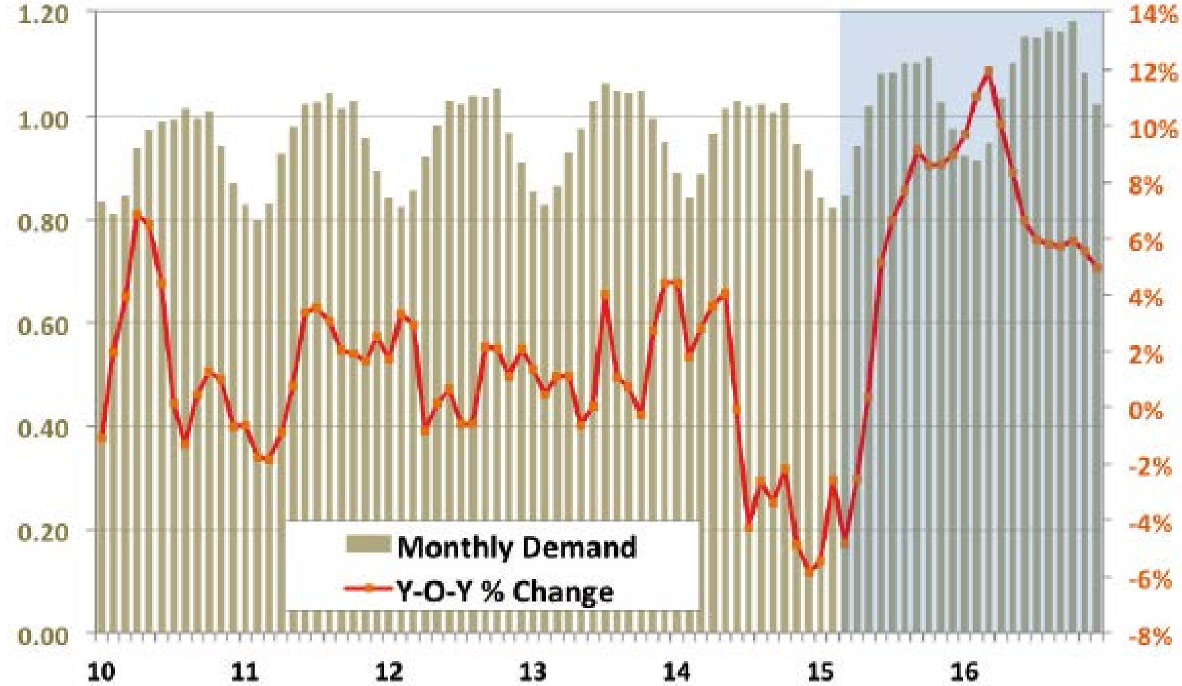
Plywood has been produced at commercial scale for many decades, and the technology is well proven and mature. In many cases, plywood layup lines are located at the same facility as veneer peeling lines, but not always. For example, in Northern California, Roseburg Forest Products and Timber Products both operate veneer mills, producing veneer that is then shipped to plants in Southern Oregon where it is formed into plywood, Laminated Veneer Lumber and other products.

Historically, plywood was used extensively in exterior sheathing for home construction in North America, but OSB has taken over the majority of this market, leading to the shuttering of numerous North American plywood mills. While exterior sheathing is still an important product for some plywood manufacturers, the remaining manufacturers have tended to specialize in the production of other products such as flooring/underlayment, concrete form, and other specialty products. Plywood products other than exterior sheathing now make up a much larger percentage of plywood production than 20 years ago.

Total North American plywood production is estimated at approximately 11 billion square feet per year (3/8” basis), with mills expected to operate at nearly 90 percent of capacity in 2015 and 2016 according to Forest Economic Advisors. **Figure 5.8** displays the historic and projected North American softwood plywood demand.[23] As shown in the figure, demand has been relatively flat for the last five years, but is expected to increase as housing starts return to historic long-term averages (about 1.5 million starts nationally). FEA also projects prices for ½” Western 5 ply softwood plywood, (a grade and thickness representative of the broader industry) to hold relatively steady in the $475 to $500 per MSF (3/8”) range through the end of 2016.

[23] Forest Economic Advisors. Structural Panel Advisor. April 2015. www.getfea.com

Figure 5.8 – Historic and Projected North American Softwood Plywood Demand (Billion Square Feet (3/8" basis))



5.4.1.2 Laminated Veneer Lumber

LVL, or Laminated Veneer Lumber, is a composite wood product made from glued together layers of veneer. The manufacturing process is similar to plywood. However, in contrast to plywood, in which the wood grain in each ply is oriented at a 90 degree angle to the adjacent layer, the grain in adjacent plies of LVL is all oriented in the same direction (see **Figure 5.9**). The veneer used in the production of LVL must be from logs that are machine stress rated for having adequate density to ensure that the product will meet design values.

Figure 5.9 – Laminated Veneer Lumber in Use as the Flange Material in a Wooden I-Joist

LVL manufacturing results in a billet (typically 3 to 4 feet wide and produced in a continuous press so the lengths can be as long as is practical). The billet has properties somewhat similar to the highest grades of lumber. However, LVL has enhanced strength properties since the manufacturing process randomizes the location of defects throughout the member. Defects in lumber, in contrast, typically extend across the entire cross section of the board (e.g., a knot) and, therefore, weaken the strength characteristics of the piece. The large billet is remanufactured (by sawing) into whatever length and width sizes are appropriate for the LVL's end-use application.

LVL is used as flange material in wooden I-joists, beams and headers, hip and valley rafters, and scaffold planking. In 1996, wooden I-joists were used in flooring systems in about one-quarter of U.S. single family homes with raised floors. Since then, LVL's market share has grown to as high as 53 percent in 2010 and has consistently been at about 50 percent for the last decade. The usage of wooden I-joists is estimated to be about 160 lineal feet per thousand square feet of floor space. The usage rate has shown about a 1 percent growth over the last five years.[24] It is important to note, however, that not all wooden I-joists are made with LVL. In 2014, about 60 percent of all wooden I-joists were made with LVL flange material, or roughly 500 million linear feet. By 2018, the proportion is expected to increase to approximately 65 percent, or 650 million linear feet according to Forest Economic Advisors. LVL demand is expected to reach 107 million cubic feet by 2017. Forest Economic Advisors estimates that an additional 4 million cubic feet of capacity will need to come online by 2016 and 20 million cubic feet of additional capacity by 2017. Existing plants are forecast to operate at 90 percent of capacity.[22]

LVL manufacturers must have third party certification, which most manufacturers achieve through the APA (The Engineered Wood Association). The certification program ensures that their product meets their design values. These design values ensure that the product will not fail in structural applications. Daily quality control tests are standard for LVL, with testing of the modulus of elasticity, the modulus of rupture and the tension. The APA also audits the quality control process monthly to ensure their third party certification.

5.4.2 Positive Aspects of Veneer – Plywood/LVL

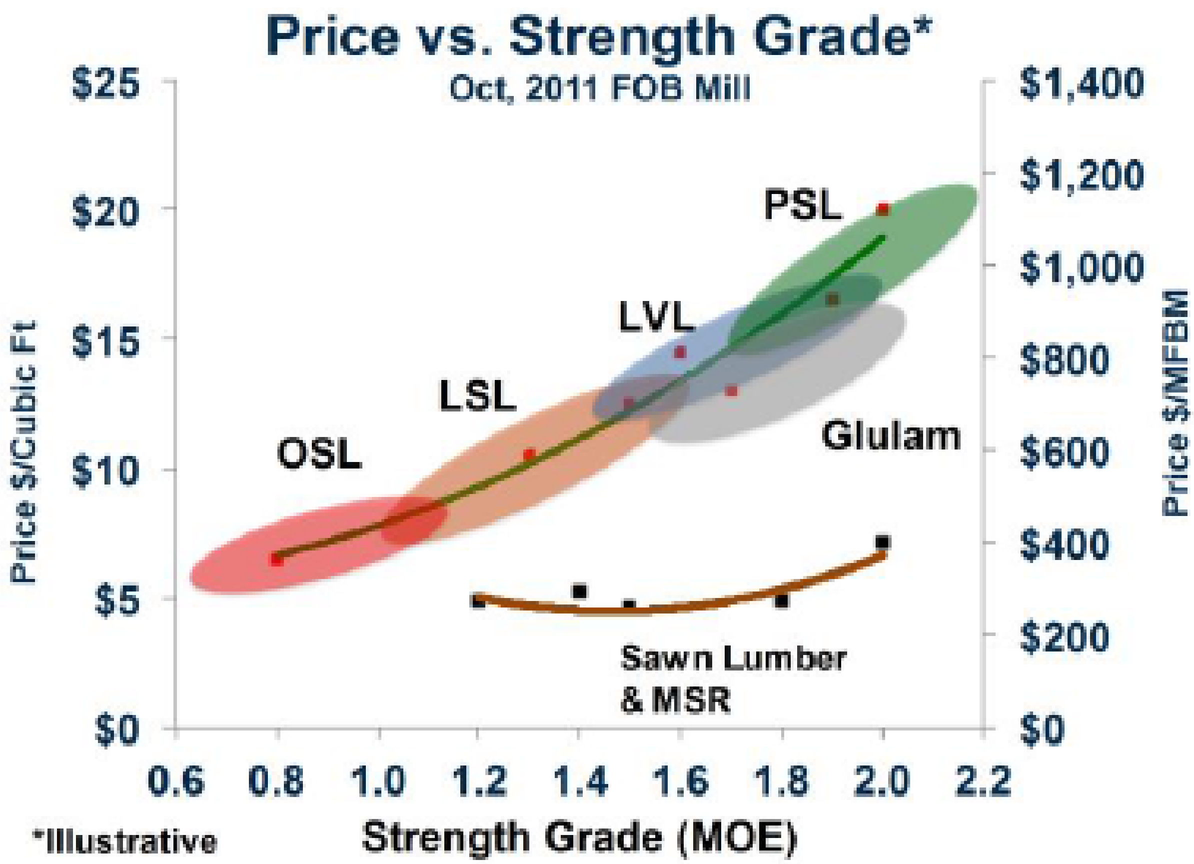
The forest industry stakeholder workshop attendees identified the following positive aspects of Veneer – Plywood/LVL projects in California:

- *The strength to weight ratio is higher for LVL and plywood than solid lumber or OSB* – This characteristic of engineered wood products increasingly makes them a preferred choice in the marketplace as evidenced by the increasing market share of wooden I-joist use in home construction.
- *High value, flexible product stream* – As previously described, the production of veneer is the first step in a manufacturing process that leads to the production of plywood or LVL. Within each of those product categories are a number of specialty applications, including flooring/underlayment, concrete form, and other specialty products for

[24] Forest Economic Advisors. 2014. Quarterly Engineered Lumber & MSR Forecasting Service. www.getfea.com.

plywood and wooden I-joists, headers and beams, hip and valley rafters, and scaffold planking for LVL. This diversity in end-products allows manufacturers to tailor production to meet market demands. **Figure 5.10** displays the high value of LVL relative to several other engineered wood products including glulam lumber, OSL – Oriented Strand Lumber, LSL – Laminated Strand Lumber, PSL – Parallel Strand Lumber) and to sawn lumber and MSR lumber.[25]

Figure 5.10 – Value of LVL Relative to Other Engineered Wood Products



- *Flexible raw material uses* – The production of veneer can be accomplished from a variety of species and from a variety of log sizes. This is advantageous in terms of being able to secure enough raw materials. However, for certain end products certain species (e.g., Douglas fir) have more desirable characteristics. Thus, this advantage is somewhat contingent on the specific end product being produced from the veneer.

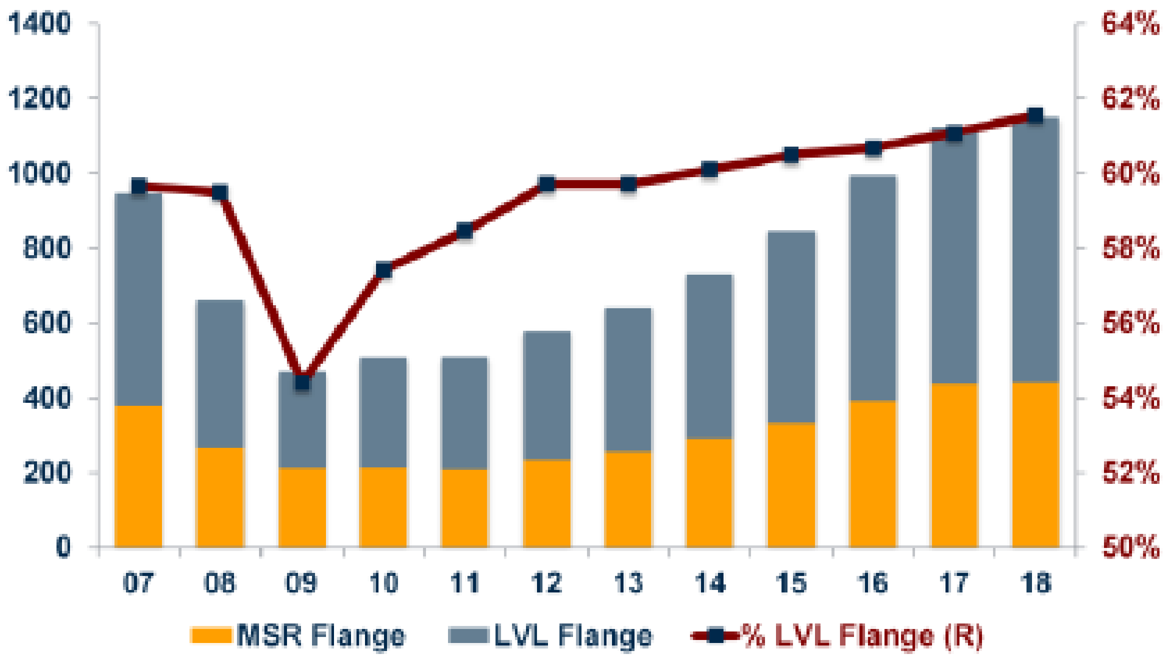
- *Large consumer of timber volume in single facility* – A goal of this study is to identify business opportunities that will allow the U.S. Forest Service to increase the pace and scale of forest restoration activities. Veneer manufacturing plants tend to be relatively large consumers of raw material. Thus, a single new facility will consume a relatively large volume of raw material, especially if designed to be able to process small diameter

[25] Forest Economic Advisors. 2014. Quarterly Engineered Lumber & MSR Forecasting Service. www.getfea.com

logs, which in turn translates into the ability to treat more acres with forest health and wildfire hazard reduction management prescriptions.

- *Plywood is labor intensive and has the potential to create an abundance of jobs* – The process of manufacturing veneer and ultimately plywood or LVL requires a relatively large amount of labor, especially in the latter stages of product manufacturing where remanufacturing defects (e.g., repairing knotholes in plywood panels) cannot be readily automated.
- *Plywood and LVL are likely to add value to small diameter timber* – As previously described, existing veneer manufacturing operations throughout the Western U.S. have proven the viability of using relatively small diameter trees for at least a portion of their incoming raw material supply. Thus, a prospective new plant in California, if designed to process a range of size materials, could potentially utilize small diameter trees.
- *LVL is a growing market; capacity will need to be added to meet forecasted demand* – As described earlier, there is an expected shortage of 2" x 3" lumber used for making I-joist flanges. In addition, the demand for I-joist usage in North America is projected to increase from roughly 800 million linear feet in 2014 to over 1 billion linear feet in 2018. **Figure 5.11** displays FEA's projected growth in I-joist usage and the increase in the proportion of flange material made from LVL.

Figure 5.11 – North American I-Joist Demand



5.4.3 Negative Aspects of Veneer – Plywood/LVL

The forest industry stakeholder workshop attendees identified the following negative aspects of Veneer – Plywood/LVL projects in California:

- *Veneer always needs to be dry for production of LVL or plywood* – This circumstance dictates that a veneer manufacturing facility must also have some type of drying system installed. This in turn means that any new facility developed in California may have to move through a CEQA process to obtain the required Title V air quality permits. Representatives from the industry estimated that this process can cost $1 million and could take up to 3 years to complete.

- *Plywood lost share in structural role due to price advantage of OSB* – While market options for other plywood end-use applications exist, plywood as an exterior sheathing material is no longer a preferred alternative.

- *Somewhat high capital cost* – Relative to some of the other technologies considered in this study, a Veneer – Plywood/LVL facility has a relatively high capital expense, which may exclude some prospective project developers. On the other hand, the greatest chance for successfully developing a Veneer – Plywood/LVL business would come from a firm that is already in the engineered wood products manufacturing business. In general, those firms are well established and well capitalized and, therefore, should have the resources needed to develop such a business.

5.4.4 Topics for Further Veneer – Plywood/LVL Analysis

The forest industry stakeholder workshop attendees identified the following unknown aspects of Veneer – Plywood/LVL projects in California:

- *Permitting unknowns – primarily air quality from emissions from drying* – Veneer must be dried prior to further manufacturing. The better understanding of the likely required permits, their timelines, and costs will be focus areas in the feasibility and business planning phase of the study.

- *Uncertainty of permitting review process* – Aside from the timeline and cost of permitting, there is the possibility that a new facility would not be able to obtain the required permits. This risk can be mitigated to some extent by selecting a site that has both the required raw material supply and air quality conditions and regulations that provide the greatest opportunity for obtaining the required permits.

- *Where are the markets?* – The market information cited up to this point has only been specific to North America. Thus, a focus of the business feasibility and business planning stage of study will be to identify the specific product applications and market areas. An additional focus area will be assessing the impact of changing building code language in some Midwestern U.S. jurisdictions that calls into question the fire resistance of wooden I-joists.

CHAPTER 6 – APPENDICES

6.1 APPENDIX 1 – TECHNOLOGY "ONE-PAGERS"

The following sections contain a series of brief technology descriptions and analysis. Please note, there are widely varying amounts of information available regarding markets, raw material supply and cost, product sales values, overall economics, and the technical aspects of each technology. Thus, the level of detail associated with each technology description varies. The technologies have been organized into four groups including energy related; traditional and engineered wood products; by-products users; and other.

6.1.1 Energy Related Technologies

6.1.1.1 Small Scale Biomass Power

Potential Impact of SB 1122 on Forestry Byproduct Usage – SB 1122 (Rubio) placed a requirement on California Investor Owned Utilities (IOUs) to purchase modest amounts of electricity from various small (3MW or less) biomass applications. Included in that mandate was the requirement to purchase 50MW of electricity from the byproducts of sustainable forest management.

The legislation required the California Public Utilities Commission (CPUC) to implement the legislation and to establish rules and regulations for the IOUs to follow. The CPUC hired Black & Veatch (B&V), a major engineering firm, as a technical consultant to assist them with developing cost data for the various technologies and for defining resource availability within various IOU territory. The CPUC also enlisted the California Department of Forestry & Fire Protection (Cal Fire) to draft the working definition of Sustainable Forest Management (SFM) required by the legislation.

The drafting and reviewing of rules and regulations occupied nearly two years at the CPUC, and a final order was approved by CPUC Commissioners on December 18, 2014.

The B&V study demonstrated that the cost to produce electricity from a small 3MW project is exceptionally high, some $219/MWH when using a $6,000/KW capital cost and $45/BDT fuel cost (with a range from $45 to $60 per BDT). B&V also found that nearly all fuel for such projects originated in Pacific Gas & Electric's (PG&E) service territory, and so they advocated that 47MW of the 50MW requirement fall on PG&E, with only 2.5MW allocated to Southern California Edison (SCE) and 0.5 MW to San Diego Gas & Electric (SDG&E).

The financial assumptions in the B&V model were that the facility would be owned by a private taxpaying entity and that no tax advantages, credits, or low cost financing would be available. Some of the key metrics of the model were:

- Debt/Equity ratio of 60/40
- Debt rate of 7 percent for 15 years

- Equity cost of 12 percent
- Depreciation using 7 year MACRS on all capital cost
- Federal/State combined tax rate of 40 percent
- 2 percent annual inflation on O&M and fuel cost
- Annual capacity factor of 85 percent
- Heat rate (mid-range) of 16,500 BTU/KWH
- 3MW net generating capacity
- Gasification technology and 3 1MW internal combustion engines
- No value given for other byproducts
- No unusual interconnection issues or costs
- Following startup, no annual capital expenditures
- Project life of 20 years with no terminal value or cost
- 2013 dollars

As stated earlier, the previous set of metrics yields a levelized required power selling price, for a 20 year Power Purchase Agreement (PPA), of $219/MWH. B&V also showed a potential range of $148-281/MWH, depending on assumptions.

Beck has reviewed the known list of potential SB 1122 projects being contemplated and found that most have some governmental agency involvement and most are located in poorer rural communities that would likely qualify for New Market Tax Credits (NMTCs), which are mechanisms to lower debt costs and equity requirements. Also, for at least the last decade, there has been some form of tax credit (production or investment) or grant available to biomass projects from the federal government, even though they occasionally expire and must be renewed by congress.

Taking the above into consideration, Beck speculates that it is likely that, with $45/BDT fuel, a 3MW rural project could accept a levelized PPA price of $180-200/MWH for a 15-20 year agreement.

The Cal Fire report to the CPUC identified 4 types of fuel that they determined met the intent of SB 1122 as being byproducts of SFM. The four are:

1. Fuels from fire threat reduction projects
2. Fuels from fire safe clearance activities
3. Fuels from infrastructure clearance projects
4. Fuels from other sustainable forest management

The legislation indicates that 80 percent or more of fuel be from one of these categories and that recordkeeping/reporting be completed annually to provide verification.

On December 18, 2014, the CPUC decision (D-14) codified much of the previous information and laid out the following program for implementing the 50 MW sustainable forest management portion of SB 1122. Key provisions include:

- Program to begin immediately, with IOUs given 45 days to submit details for approval (now lapsed)
- 50 MW total requirement (47MW of which is PG&E's responsibility)
- $127.72/MWH project levelized starting price, with statewide price pool
- Use of Renewable Marketing Adjusting Tariff (ReMAT) mechanism to adjust prices
- Minimum of 3 projects in initial queue to allow price change modification to begin
- Once first 1 MW accepts a contract price, the minimum number of projects in the queue for the price change modification to again go into effect increases to 5 projects
- Use of existing ReMAT PPAs for contracting
- Program terminates 60 months after first offering
- PG&E, SCE to offer 6 MW in each auction, SDG&E to offer 3 MW
- Project must be in service territory of one of IOUs
- Transmission upgrades must not exceed $300,000 per project unless bought down to that level by developer
- Must be connected to IOU distribution system
- 3 MW maximum "nameplate" rating
- Must qualify at California Energy Commission (CEC) for California Renewable Portfolio Standard (RPS)
- Must be a Federal Energy Regulatory Commission (FERC) Qualifying Facility (QF)
- CPUC staff to review maximum price if it rises to $197/MWH

The ReMAT program has been in place for several years to satisfy SB1132 requirements and is used by the IOUs to purchase small (3MW or less) renewable power of all types. In PG&E's case there are a set of preconditions that must be satisfied before a project will be allowed to be placed into the ReMAT queue. Those preconditions include:

1. Must be physically located in IOU territory
2. Must be an Eligible Renewable Resource (ERR)
3. Must be a federal QF
4. Contract Capacity cannot exceed 3MW

5. Interconnection study, in some form, must be completed to indicate interconnection is feasible
6. Must have 100 percent site control
7. At least one member of development team must have experience with same technology/size project
8. This must be the only project being developed at site
9. Cannot have accepted incentives from California Solar Initiative
10. Cannot be doing Net Energy Metering at site

Once the initial queue is complete, the IOU will hold the first bimonthly subscription of 6 MW of PPAs. Queue position is determined by date of acceptance or by random drawing if on same date. The initial price will be $127.72/MWH for the PPA duration. The IOU will offer PPAs to the first 6 MW of projects in the queue. If no takers, they will go through the queue with the offering.

Assuming there are no takers among the 3 or more projects in the queue, the following bimonthly sequence will occur:

- First Bimonthly Adjustment: Original price + $4/MWH
- Second Bimonthly Adjustment: Revised price + $8/MWH
- Third Bimonthly Adjustment: Revised price + $12/MWH
- Fourth and Subsequent Bimonthly Adjustment: Revised price + $12/MWH

The price can also go <u>down</u> according to the same schedule if the 6 MW is fully subscribed. One unique feature in the bioenergy ReMAT will be that once 1 MW is subscribed, the queue must expand to 5 projects before the price can begin to move again. Assuming that projects of this size can accept prices in the $180-200/MWH range, as speculated, it would be 12 months into the program before an acceptable price is reached, and the price would be close to the trigger price ($197/MWH) at which the CPUC would investigate a price cap.

Once an acceptable price is reached, the project will have 10 days to accept/reject the award. Once accepted, the project will be offered the standard ReMAT PPA. Some of the key provisions of this PPA are:

- Term of 10, 15 or 20 years
- Price fixed for term of PPA
- All sales net of station service
- Contract can be buy all/sell all or excess sales only
- Contract Capacity (CC) cannot exceed 3,000 KW
- Time of day pricing is applicable
- Can deliver up to 110 percent of CC in an hour

- Can deliver up to 120 percent of Contract Quantity (CQ) annually
- All Green Attribute & Resource Adequacy benefits to IOU
- 2 year energy guarantee of 180 percent of CQ
- Subject to California ISO forecasting, scheduling, penalties
- Project to post $20/KW collateral for life of contract
- Project on line within 24 months of PPA signing
- Typical definition of Green Attributes, so that any fuel emission related GHG benefits, for instance, would remain with project and not IOU

Analysis – the full implementation of SB 1122 may well be the only near term opportunity to expand biomass utilization from forestry byproducts in California. It comes at a time when, ironically, low wholesale electric prices and contract expirations are causing the shuttering of numerous larger biomass power facilities, several in forested areas. However with only a 50MW limit, the new facilities will not replace those being lost in terms of processing capability; they will be more targeted geographically and may be configured to produce other high valued byproducts.

These small projects could not hope to compete economically in the California wholesale power market without a program such as SB 1122. These will be, essentially, community scale projects designed to support local efforts to lower fire risk and restore the local forest to health and vitality. They will be small enough that they will not require guaranteed access to large swaths of federal forests over extended periods, something very difficult for federal land managers to provide.

Although sponsoring community groups may have hoped to base their projects on the production of newer biofuels or biochar, it will be the standard production of electricity from biomass that allows a long term assured revenue stream so that financing can be obtained. If California "doubles down" on a long term commitment to GHG reduction, the facilities can transition to other uses, but will likely begin life as electric power producers with perhaps small quantities of other byproducts.

In putting together a project to compete for a SB 1122 ReMAT contract, the benefits of finding a legitimate steam host so that a Combined Heat & Power (CHP) project can be proposed are quite substantial. Beck performed a quick analysis to show that a 3MW project supplying an average of 7,000 pounds per hour of low pressure steam to a host formerly burning $7/million BTU gas can lower the acceptable power sales price by $25/MWH. This would move the project up in the IOU queue and be able to start construction well ahead of a "power only" project. It is Beck's experience that community scale CHP projects that displace fossil fuel also have much wider public acceptance than standalone projects.

There are negative aspects to the SB 1122 program as well. Large swaths of California forest fall outside the service territories of the three large IOUs subject to SB 1122. Other IOUs, such as PacifiCorp and Liberty Utilities West, serve forested areas, but are not included in SB 1122.

Publicly owned utilities, such as Surprise Valley Electric, Plumas-Sierra Electric, Trinity PUD and even the Los Angeles Department of Water & Power, serve substantial forested areas.

Clearly, a project designed to compete for a SB 1122 contract could be configured as either a gasifier/internal combustion engine or a steam boiler/steam turbine-generator. If the developers have designs on future production of biofuels or biochar, the gasifier may offer more options and flexibility. If a substantial thermal host is available requiring steam, the boiler/steam turbine may get the nod. It should be emphasized, however, that the ReMAT contract will require delivery of 180 percent of the annual Contract Quantity each two year period, so reliability and proven technology must be emphasized. Though some finesse can be applied by virtue of being able to deliver up to 120 percent of Contract Quantity in any one year, an unproven technology may still result in the termination of the contract before the bugs can be worked out.

A final issue of concern with SB 1122 projects is whether it will be possible to deliver 3MW net within the constraints of the contract. All auxiliary load must be served first, meaning that perhaps 3.3-3.5MW gross would be required to deliver 3MW net. It would appear, in some definitions, that a project is limited to a nameplate of 3.0MW. If this is the case, and only a net of 2.5-2.7MW can be delivered, it will again raise the power selling price to above that projected by B&V, which assumed a delivery of 3.0MW.

Bottom line is that SB 1122 implementation appears to be the only likely vehicle to get projects involving the utilization of the byproducts of forest activity moving in the near term. With the ReMAT formula, prices will rise relatively quickly (provided three are in the queue) to levels to support the projects, so long as the IOUs or CPUC price cap review do not truncate the process.

6.1.1.2 Butanol/Other Drop In Fuels

Butanol is a four carbon alcohol seen as a potential replacement for corn based ethanol in gasoline. It is considered to be a second generation biofuel for purposes of the federal Renewable Fuel Standard (RFS) as it can be produced from sugars derived from cellulosic materials. It is considered a "drop in fuel" as it is conceivably blendable with gasoline directly at the refinery rather than being blended at terminals as ethanol is today. There are several other "drop in biofuels" being developed, but this discussion of butanol will serve to represent the status and potential of other fuels as well for purposes of this study.

Butanol is much more compatible with gasoline than ethanol in existing vehicles since its heat content is 90 percent that of gasoline and it has an equivalent octane rating. Its lower fuel/air ratio requirement means that it avoids much of the "rich mixture" requirements of ethanol that can damage engine components.

Butanol does not absorb water as much as ethanol does, so it is not corrosive to pipelines, and could be shipped in existing gasoline pipelines, creating a substantial advantage. Butanol is far more viscous than gasoline, however, having a viscosity similar to diesel fuel.

In Europe, some producers are making a product of 85 percent ethanol and 15 percent butanol for use in E85 equipped vehicles. The product, called E85B, allows a consumer to purchase a fuel that is totally made from organic materials. When butanol is blended with gasoline, the more similar characteristics allow a higher blend than the typical 5-10 percent ethanol before engine modifications are required. Refiners expect this blend limit for butanol to rise to 8-16 percent as a minimum.

Butanol is produced via a fermentation process, but the yields are low as byproducts of acetone and other organic acids are formed during the fermentation process. At some point in the fermentation process the concentration of butanol becomes toxic to the organisms producing it and the process stops. Recent research has allowed extraction of butanol from the reactor at lower concentrations to avoid this phenomenon, though this complicates the downstream refining process. More distillation is needed from dilute fermented broths.

Like all biofuels, butanol development and commercialization suffers in an era of low crude oil prices. The granting of EPA waivers to refiners from the RFS provisions has also not advanced the cause of *drop in* biofuels. *Drop in* biofuels, such as butanol, if derived from cellulosic sources, avoid the "food vs. fuel" debate that has so damaged the reputation of corn based ethanol. There are actually reports of ethanol plants being converted to butanol production, because butanol is a superior liquid fuel compared to ethanol, but yields will be much lower and costs substantially higher.

If there is a long term commitment to greenhouse gas reduction from the transportation sector at the state and federal levels via the RFS or other methods, the future of drop in biofuels such as butanol should be bright. Refiners will need the higher blend limits offered by butanol over cellulosic ethanol. Also, the ability to ship the mixture via existing pipelines and tanker ships offers a substantial advantage over the more complicated blending at terminals required with ethanol.

6.1.1.3 Cellulosic Ethanol

Cellulosic Ethanol is ethanol made from fermenting sugars derived from lignocellulose material that is found in all plants. Cellulose provides the cellular structure for all plants and because cellulose makes up nearly half of all plant biomass, cellulosic ethanol is considered the largest potential source of biofuel in the near future.

Cellulosic ethanol is produced by extracting the cellulose from plants, then using enzymes or acids to hydrolyze the cellulose molecules into sugars. Once the cellulose is converted to sugars, the sugars are fermented into ethanol a two carbon alcohol. The alcohol is then distilled to near 100 percent, the end product being a clean-burning liquid fuel.

The process has three stages: Hydrolysis, fermentation, and distillation. Of all the stages, hydrolysis is the biggest challenge. With acids, energy is required to accelerate the process and there are byproducts from sugar degradation. With enzymes, the rates of hydrolysis are low due to the large size of enzyme molecules required to effectively penetrate the cellulosic structure. Concentrations of sugars are usually low which means more energy is required in distillation stage.

The benefit of cellulosic ethanol is that the feedstock required to produce the fuel is renewable. The process to produce the ethanol uses biomass and lignin from the feedstock and therefore has lower greenhouse gas emissions. Environmental life cycle assessments of the Alpena bio refinery found that the entire life cycle greenhouse gas emissions from the plants cellulosic ethanol were only 25 percent that of petroleum-based gasoline.

Progress has been slow for commercial production of cellulosic ethanol. One additional challenge associated with large scale cellulosic ethanol production is the pretreatment of the lignocellulose. Pretreatment is needed to free the cellulose from the lignin and to loosen its crystalline structure. This allows the cellulose to be accessible for a subsequent hydrolysis step. Pretreatment can be done chemically or physically. Physical pretreatment refers to size reduction of the physical biomass while chemical pretreatment involves chemicals that remove barriers so the catalysts (acids or enzymes) can have access to the cellulose.

Commercial quantities of cellulosic ethanol generated from woody biomass that meet the EPA standards have just recently gone to market. American Process Inc. (API) is an Atlanta-based company that develops renewable materials, fuels and chemicals from biomass. The company is producing cellulosic ethanol at a demonstration plant in Alpena, Mich.

Another company, Colorado based Red Rock Biofuels, has received funding to build a refinery in Oregon. The company received a $70 million federal grant in addition to $130 million from investors. The refinery is being located in Oregon because of the close proximity to feed stock. The company has a long term agreement with the Collins Company to supply the feedstock. The refinery will take approximately 140,000 tons of needles, sawdust and tree branches a year. The output will yield 12 million gallons of jet and diesel fuel.

For this project, it is not a likely outcome for the management of small diameter logs in California. The production of cellulosic ethanol is still in its early stages and it has not been proven as an economically viable option. At best, most developers claim a high yield of 65 gallons of ethanol per oven dry ton of wood feedstock. Compared to corn ethanol which has a yield of almost 50 percent, wood ethanol is relatively low yield, other factors notwithstanding. It is also worth noting that with other feedstocks such as corn and sugarcane, hydrolysis is not an issue because the sugars are easily derived thus processing is much simpler. The capital costs for cellulosic ethanol are high and it is still being determined if the technology is economically feasible.

6.1.1.4 <u>Firewood</u>

Small diameter timber can be burned as firewood. However, commercially sold firewood more typically is made from trees with a slightly larger diameter. Firewood made from larger logs is preferred by most consumers because it burns longer and does not contain as much pitch. Larger wood is also desirable from a producer’s perspective because productivity is higher and, therefore, manufacturing costs are lower. Many firewood producers indicate they prefer raw material in the 10 – 14” diameter range.

Firewood is commonly sold in bulk (by the cord or truckload) directly to users. It is generally sold on a delivered but not stacked basis (stacking may be done for an additional fee). In recent years, firewood also has been sold in small bundled units, often shrink-wrapped in plastic, to consumers at grocery or similar retail stores. Each bundle typically contains approximately 0.75 cubic feet of wood, although other bundle sizes are available. When sold through large chain stores, the bundles are palletized and stretch wrapped to facilitate warehousing and shipping.

Demand for firewood is significant in California. For example, as of the 2000 U.S. Census, 1.8 percent (or a little over 200,000) of California’s 11.5 million occupied housing units at the time relied on wood as the primary source of heat for the home. According to data from the Energy Information Administration, the average home in California uses about 38 million BTUs of thermal energy per year for home heating. This translates into approximately 2.2 bone dry tons of firewood per home per year or about 400,000 bone dry tons of firewood statewide. In addition, there is a market for firewood used at campsites, in backyard fire pits, and as an occasional use in a home fireplace. The size of this “convenience” or “packaged” firewood market is difficult to predict, but is also significant. BECK estimates that it may be as big as 1/4 to 1/3 of the home heating firewood market.

The firewood that does make it to market from commercial producers is distributed in a combination of direct to customer for bulk material and through grocery, hardware, feed and seed, and big box stores for bundled and palletized firewood.

An obstacle to developing a large-scale bulk firewood operation is that many firewood users cut their own firewood each year. The market for packaged firewood, on the other hand, can be serviced by a single large producer because, in that case, the consumer is generally willing to pay a higher price for the firewood bundle for the “convenience” of being able to purchase only the small amount he or she needs.

6.1.1.5 Fuel Bricks/Densified Fire Logs

Similar to pellets, wood briquettes (also fire logs or fuel bricks) are another wood densifying technology. Like pellets, wood particles are compressed under high pressure to form the fuel bricks. However, the dimensions of the bricks are much larger than pellets – generally about the size of a mortar brick. This difference in size is important because it means that homeowners who burn briquettes can use their existing wood stove or fireplace. This is in contrast to wood pellet users who need to purchase a stove specifically designed to burn wood pellets.

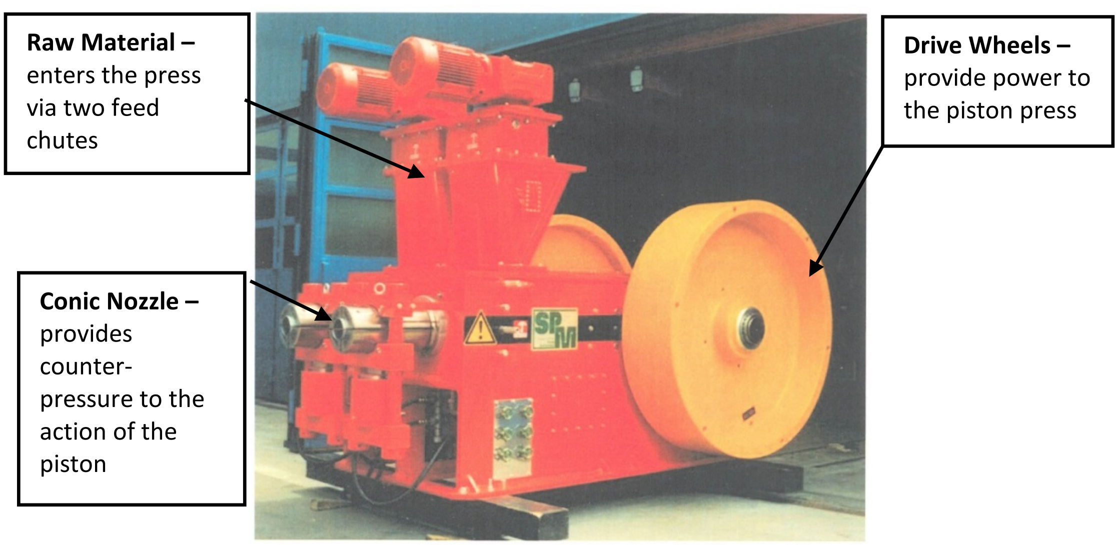
Briquetting requires raw material (wood fiber) dried to approximately 12 percent moisture content (MC). It also must be milled to a uniform size (< ¾”), and then compressed with either a hydraulic or mechanical press. Mechanical briquetters are often used in applications where briquetting occurs around the clock. Mechanical briquetter machine capacities range from 0.25 to 2.0 tons per hour.

A briquette plant could use a conventional rotary dryer similar to those used in many pellet plants, but in this case we have assumed the use of a mechanical drying system. This system uses electrical power to create a high pressure environment that mechanically removes moisture from the fiber. An added benefit to this approach is that material dried with this system does not require subsequent size reduction.

As shown in **Figure 6.1**, the dried raw material is delivered to the press via two feed channels to insure an even and continuous supply to the press. As the material is feed to the press, large wheels drive the press piston. Counter-pressure to the press piston is provided by a conic nozzle. As a result of this process, wood briquettes are formed. The briquettes can vary between cylindrical and square cross-sectional shapes depending on the shape of the conical head. The shape and size of briquettes vary, but most are between about 2 inches in height and width and about 5 inches in length.

The high pressure in the press causes the temperature of the raw material to rise, which in turn causes the lignin in the wood to "plasticize". When the lignin reaches this state, the material is more easily extruded through the conic nozzle. The resulting briquettes are then cooled, which causes them to "set" in their final form. No added adhesives are used in the manufacturing process. Finished briquettes are dense and durable, which means they can be economically transported long distances with little degradation. Finished briquettes typically contain less than 10 percent moisture (by weight). Briquettes are similar in density to pellets (about 40 pounds per cubic foot), but no grading standards exist for briquette quality.

Figure 6.1 – Wood Briquetter



Source: Pawert – SPM AG, Basel Switzerland

Briquette manufacturing generally has similar raw material requirements to pellet manufacturing (i.e., dry, sized, and somewhat clean). However, briquette raw material does not have to be reduced to as small of a size (+/- ¾") as pellet raw material. In addition, because ash content is less of a concern, some bark or other contaminants can be tolerated, and therefore logging slash is considered a suitable raw material.

Like pellets, briquettes can be used for residential space heating. However, an advantage briquettes have over pellets is that their use does not require the homeowner to purchase a special heating appliance. In other words, the homeowner can use his or her existing wood stove or fireplace to burn the briquettes. This is also an advantage over other heat sources because, unlike pellet stoves and oil furnaces, fireplaces and wood stoves can still operate in the event of a power outage. The downside of the compatibility with existing wood stoves and fireplaces is that the briquettes must be priced competitively with firewood (approximately $150 to $200 per ton) or else homeowners will simply continue using firewood. Some factors do allow briquettes to command a higher price than firewood. First, briquettes can be made available at any time, whereas properly seasoned firewood may not always be readily available. Briquettes are already low in moisture content and, therefore, do not require seasoning, while green firewood does.

Also, users have cited the convenience and ease of using the uniformly sized and shaped bricks versus firewood and note that they are cleaner, avoiding the mess of insects, dirt, and loose bark in the home. Briquettes are also cleaner burning than firewood and, if used widely in communities with air quality restrictions, could lead to fewer “no burn” days. Finally, since the densification process packs more BTUs per unit of space, a year’s supply of briquettes can easily be stored in a smaller space than a year’s supply of firewood. **Figure 6.2** depicts two pallet loads of briquettes (equivalent to two cords of firewood) stacked in a customer’s garage.

Figure 6.2 – Two Pallet Loads of Briquettes Stored In A Garage (Roughly Equal To 2 Cords of Firewood)

Briquettes can be burned in most boiler systems. Thus, any industrial or institutional entities with a boiler are potential markets for briquette producers. In addition, briquettes can be converted back to dust with relative ease for co-firing in suspension with coal. A recent trend in Western Canada and the Northwestern U.S. is the installation of briquette machines at millwork businesses. According to BECK industry contacts, all of the briquettes to be produced by these operations have been presold to greenhouses for greenhouse heating.

The briquetting equipment shown in **Figure 6.1** has a production capacity of 1.5 tons per hour. Thus, assuming 6,000 operating hours per year, a plant could produce 9,000 tons of briquettes annually. If a plant were developed at this size and market demand warranted adding production capacity, then additional machinery could be purchased or the plant could be operated for more hours per year. Up to a certain point, increasing capacity by adding more machines could be accomplished without increasing fixed costs and hourly labor costs because the machinery is so automated that the same number of workers would simply oversee two (or more) briquetters rather than the single machine.

BECK contacted several briquette equipment manufacturers and used reference information from previous BECK pellet plant feasibility studies to estimate a "high level" budgetary capital costs for a plant equipped with one machine, as shown in **Figure 6.1**. These costs are summarized in **Table 6.1**.

Table 6.1 – Projected Briquette Mill Capitalized Expenses

Item	Estimated Cost ($000)
Purchased and Fabricated Equipment [1]	759
Equipment Delivery and Installation [2]	808
Land, Building, & Site Prep	391
Sub-Total	**1,958**
Contingency (10%)	196
Total Estimated Installed Cost	**$2,154**

Notes:

[1] Purchased equipment includes briquette press, automatic briquette cutting saw, misc. auger and feeding systems, automated packing system, front end loader, truck dump, and bio-gas dryer.

[2] Includes freight, mechanical and electrical installation, fire protection, spare parts, engineering and on-site project management.

Given the relatively small scale of the business that could be developed with this technology, BECK concludes that it should not be considered for detailed feasibility analysis.

6.1.1.6 Large Scale Biomass Power

For at least 3 decades, California has been the nation's leader in larger standalone biomass power facilities. When cogeneration facilities at forest products facilities are included, California, at one point in the mid-1980s, had over 60 facilities producing nearly 800MW of power – about half of the nation's total. California's policies when implementing the federal Public Utilities Regulatory Policy Act (PURPA) of 1978 were quite favorable to renewable producers, and there was an explosion of biomass power construction lasting until about 1990.

The plants were essentially all in the range of 10-50MW, with maximum size truncated at a net of 49.9MW so as not to trigger regulation by the California Energy Commission (CEC). The plants were built to utilize as fuel a combination of urban wood, forestry residuals and agricultural waste. A network of plants were constructed in the Sierras, from Burney in the north to Bakersfield in the south that were ideally suited to accept the byproducts of forest management activities.

The plants were built on the strength of 20-30 year Power Purchase Agreements (PPAs) with California's Investor Owned Utilities (IOUs). These PPAs featured substantial capacity payments earned during on peak periods, initial 10 years of high fixed energy prices and the remaining years at Short Run Avoided Cost (SRAC). The expiration of nearly all these contracts falls in the time period of 2012-2020.

Shortly after the signing of most of the PPAs, however, prices for oil and natural gas fell substantially, as did the calculation of SRAC. This left the PPA prices perched well above market price for wholesale electricity. The IOUs offered to buy back the power contracts and several were sold with subsequent plant closure.

By the late 1990s nearly all the plants were beyond the 10 year "cliff" in energy prices that resulted when they left the fixed rates for SRAC. At this point, nearly all plants were operating at a loss. The deregulation of California's electricity market followed shortly by the "electricity crisis" in California provided a few years of opportunities for the biomass power facilities, but the return to normalcy in the early 2000s left almost all plants struggling financially.

For nearly 15 years now, the fleet of plants have continued to persist to the end of their contracts in order to earn capacity payments and to avoid the repayment of early year capacity overpayments that would be triggered by a premature contract cancellation. But, at the end of their initial contracts, most plants are closing due to a lack of new opportunities for large plants. Utility auctions are yielding low prices, even for bundled renewables, that will not support a technology option that must pay for the processing and delivery of its fuel.

Along with plant closures comes a dismantling of the fuel supply infrastructure that has been built up over the last 3 decades. No longer can a forest thinning operation or an orchard removal be assured of an outlet for its otherwise non-merchantable output.

A Possible Path Forward – The existing biomass plants provide the following environmental and societal benefits, including:

1. Displacing fossil fuel carbon emissions
2. Providing lower carbon disposal options for waste management, forestry and agriculture
3. Participation in forest fire reduction efforts
4. Improving air quality by displacing open burning
5. Providing a home for products of forest restoration efforts, etc.,

If those plants are to survive, it will have to be within the context of its carbon reduction programs. The electricity system, plus targeted public funding, has supported these plants to date, but a staggering quantity of new renewable development under contract and persistent low natural gas prices make this an unlikely solution going forward.

California needs to preserve (and expand) the network of plants and the millions of tons of waste fuels they consume per year. California's population continues to expand along with the attendant waste generation. The agricultural sector remains huge and continues to trend towards woody biomass crops (grapes, almonds, olives) that need waste disposal. Ever worsening forest fire seasons underscore the need to expand thinning of the stressed overstocked forests. California clearly risks taking backward steps in carbon emissions if these sectors revert to open burning or decomposition of their wastes, or the standing carbon inventory is lost due to fire.

One concept would be to retask the existing fleet of plants with becoming CO_2 removal stations for the agricultural, forest and urban areas of California. Trees and agricultural crops would continue to absorb CO_2 and exchange it for oxygen. When all other higher valued sequestration products have been produced from the trees, the remaining waste would be delivered to a CO_2 removal station for combustion. One change from current practice would be that the plants would be equipped with state of the art CO_2 capture technology and the CO_2 would be sequestered underground, perhaps as an enhancement to California's current oil recovery activities.

Biomass power facilities are ideal candidates to provide this "service" as they have the richest CO_2 stream among California power sources. Current carbon offset prices will not support the capital expense and risk involved by the owner in installing unproven carbon capture technology. This large scale program could become a candidate for expenditures from the public sale of carbon allowances, beginning with a scientific study of the potential and progressing to the development of a protocol for such removal. Scientific study of this concept may well conclude that carbon capture and sequestration from biomass plant exhaust is one of the more cost effective carbon reduction techniques available.

Post 2020, if California remains on a carbon reduction pathway, the dual revenue stream from sales of electricity and carbon offsets may well save and revive the California biomass power industry. Absent something as dramatic as this program, large biomass power facilities will continue to close.

6.1.1.7 Pyrolysis

Pyrolysis is the thermal decomposition of organic matter in the absence of oxygen. The products are typically gases, liquids and a high carbon char. A typical yield from a biomass feedstock is 10-20 percent gases, 15-25 percent char and 60-70 percent oil. The gases are typically burned to produce the necessary process heat, and there may be an excess, depending on conditions. Pyrolysis is typically carried out at moderate temperatures in the 400 - 550°C range.

The char product can be used as charcoal or biochar, or further gasified to produce additional heat. The char contains virtually all of the original ash in the biomass feedstock. Unlike modern production of charcoal, which also uses a pyrolysis process, current research focuses on the maximization of liquid fuels rather than the solid charcoal currently produced.

Some of the drawbacks to pyrolysis are that the biomass must be dried to less than 10 percent moisture to avoid excess moisture content in the oil product. In addition, the particle size entering the reactor must be quite small if process efficiency and oil yield are to be maximized. The product oil is also very low in pH (2-3). All of the above issues add to project capital cost and complexity.

Pyrolysis is primarily carried out to produce liquids that can be upgraded to motor fuel or other chemicals. USDOE refers to the liquid product as "platform intermediates" for production of high valued chemicals and materials. Mobile pyrolysis units have been touted for some time as a solution to the high cost of transporting green biomass from the woods, as pyrolysis oil has an energy density 8 times that of green biomass. The oil can also be burned directly in a modified internal combustion engine-generator, but overhaul cycles will likely be short due to the oil characteristics.

Though pyrolysis oil offers some advantages for conventional thermal and electric generation over direct combustion due to the feedstock freight savings mentioned above, that is not a likely route to success for the technology. In order to have a large scale penetration into the biomass market, pyrolysis oil must be seen as a low carbon replacement for fossil transportation fuels. To be used in this way, refineries and perhaps fuel standards would need to be modified to accept this high moisture, low pH, low heating value fuel. One thing that could create such a demand is sustained high crude oil prices driven by chronic shortages, the exact opposite of what we are seeing today.

A perhaps more likely route is a national commitment by the U.S. to a low carbon transportation fuel future backed by regulatory goals and standards. The USDOE looked at various low carbon transportation futures in 2013, with 2050 as the date of full implementation. In these scenarios, pyrolysis oil from various biomass feedstocks plays a pivotal role. In some scenarios, pyrolysis oils represent some 30-45 percent of total fuel volume in 2050, with biomass needs approaching 800 million bone dry tons per year, with as much as 65 million dry tons annually of woody biomass. In these scenarios, pyrolysis oil first appears in significant quantities in 2030.

California can, of course, represent a microcosm of this national system of low carbon fuels, and the California's Global Warming Solutions Act of 2006 (AB32) is a significant start in that direction. It will take substantial carbon offset credit costs, however, to cause refineries to retool in order to accept high moisture/lower heating value pyrolysis oil as a feedstock. This report covers, in a separate section, the status in the near term of the carbon markets in California for how that could influence a decision to pursue pyrolysis in California.

At this time no truly commercial pyrolysis systems exist in the U.S. However, research has been underway globally on a significant scale for an extended period. The individual unit operations are not overly complicated, and so it is likely that pyrolysis systems can be commercially developed when markets are available for the raw pyrolysis oil product in the transportation sector.

6.1.1.8 Gasification CHP

Gasification of carbonaceous materials, as a technology, has been in use since early last century when it was used to produce "town gas" for streetlights. The use of biomass as a feedstock is more recent, but has been utilized in Europe for nearly two decades to provide heat for district heating systems.

The process involves heating biomass in the partial or complete absence of air to produce a "synthesis gas" of primarily CO, H_2 and CO_2, with a small amount of methane. The gas, from biomass feedstocks, also contains tars that must be removed ahead of various downstream processes. The gas could further be refined into chemicals, synthetic natural gas, and/or possibly liquids or simply combusted to produce heat and power.

There seems to be as many variations in gasifier design as there are potential suppliers. Designs involve updraft or downdraft flow, various fluidized bed types, and there are even designs that incorporate a bed material such as sand or limestone. The various designs operate at different temperatures to vary the mix of the gas. In addition, the pretreatment and drying requirements vary widely. This report will not attempt to sort through these numerous designs to select favored technologies for the California forest situation. While this is a relatively advanced technology compared to some others investigated, work is still to be done on how the equipment functions when using biomass using fuels that result from forest management treatments in California (i.e., inconsistent moisture content, irregular geometry of fuel pieces, and potentially high levels of inorganic content).

In terms of products to be considered, however, this report will focus on opportunities in combined heat and power (CHP) in California. Some of the more refined products from gasification (liquid fuels, substitute chemicals, etc.) are still in their infancy. A well designed CHP system would allow for upstream synthesis gas to be removed for producing other products should processes be refined and other more lucrative markets develop.

In a typical CHP installation in Europe, the synthesis gas is treated by cooling/filtration to remove particulate matter and tars, with the resulting clean gas being combusted in a modified internal combustion engine generator. Heat is recovered for district hot water systems from the process of cooling the synthesis gas, from the engine cooling system and perhaps even from the engine exhaust stack. A typical installation may produce the equivalent of 3MW of thermal energy and 1MW of electrical energy. The efficiency of the electrical only step is 25-31 percent when measured on a lower heating value basis (LHV). A properly designed system that can continually utilize all the waste heat can exceed 80 percent in overall efficiency.

Attempts have been made over the years to replace the internal combustion engine with a gas turbine, which would allow the 25-31 percent measured conversion efficiency to rise to perhaps 45-50 percent. These many attempts have not been successful, however, as the residual tars and other particulates have destroyed the gas turbine after a short number of hours. This IC engine to GT conversion remains the holy grail of gasification proponents.

When looking to adapt this European CHP model to California, there appears to be very few obvious opportunities. California does not employ the district heating model that Europe's small and medium sized cities use. With the exception of a gas-fired system in downtown San Francisco operated by Pacific Gas & Electric, the closest systems to this model in California are consolidated steam or hot water systems that serve college campuses or prisons.

One model close to California was a biomass CHP system at the state prison in Carson City, Nevada, which ultimately failed due to several serious design deficiencies and an inadequate power contract. This system did not use gasification, however, but relied on a step grate boiler and a condensing steam turbine-generator without any process extraction.

It should be noted that the gasification CHP works best with hot water systems than with steam systems. Most of the water heating is from low grade systems that could not support steam generation. For an existing steam thermal host, a conventional boiler still may be required.

In the forested regions of California, it is possible to solve the issue of a poor market so long as the electrical output of the CHP project does not exceed 3MW. The SB 1122 bioenergy program discussed elsewhere will provide a home for 50MW of projects supplied by utilizing the byproducts of sustainable forest management. This program could provide a lucrative home for the power output of 20-40 small CHP projects over the next 5 years or so.

In terms of finding a thermal host for such facilities, however, we must certainly look beyond the community district heating model popular in Europe. In this case we must focus on college campuses, prisons, critical access hospitals, and military bases in or adjoining the forested regions of California as potential thermal hosts. These categories have in common the consolidated provision of heat, cooling and potentially electrical. In some cases, a centralized distribution system is already in place and powered by fossil fuel.

A quick survey of potential thermal hosts near forested areas in California produced the following results:

- 5 federal prisons
- 3 California prisons
- 4 University of California campuses

- 7 California State University campuses
- 26 Community colleges
- 9 Military bases

This is a total of 64 candidates for small scale CHP, not including small hospitals with the heat source being biomass gasification or traditional combustion in a steam boiler. The above list considered no sites in either the San Francisco Bay area or Southern California due to either excessive congestion or distance from forested areas, or both. Perhaps 55 of these sites are located within the service territories of the three Investor Owned Utilities subject to the SB1122 program.

Small scale gasification driven CHP presents a potential option for expanding the use of California's forests when combined with the SB 1122 bioenergy program and an appropriately matched thermal host site.

6.1.1.9 Torrefaction

Torrefaction is the thermal heating of biomass to modest temperatures (240 - 320°C) in the absence of oxygen in order to break down the fibrous structure, remove volatile materials and increase energy density. The resulting product has a heating value of 20-21 million BTU per ton (1 percent H_20) and contains about 90 percent of the original heating value of the original wood. The 10 percent heating value loss is sufficient to provide the heat for the process, once started with an outside fuel source.

The torrefied wood is often touted as a replacement for coal in industrial and utility power plants as it can now be ground readily (as is coal) for burning in suspension. It is also mentioned in some literature as a replacement for wood pellets, but no economics are provided. This latter claim may be problematic for torrefied wood from forest waste as 100 percent of the wood ash stays in the torrefied product, and ash is a major consideration in residential wood pellets.

Technically, it is likely that a torrefied wood production facility could be successfully implemented. It is simply low temperature pyrolysis, with the only products being low heating value gas and the torrefied wood product. This process should not be rejected due to technical production issues.

The real question is one of economics. This issue will be evaluated in the context of torrefied biomass as a replacement for coal or for petroleum coke at plants in California. The CEC website shows, as of July, 2014, about four plants in the East Bay burning petroleum coke (a byproduct of Bay Area refineries) and four traditional coal burning plants (1 in Fresno County, 1 in Kern County, and 2 in San Bernardino County). All of these plants are in the 25 to 50 MW size range, providing a substantial potential market.

Petroleum coke is a byproduct of petroleum refining and is a low volatile, high heating value fuel. It is burned in four fluidized bed facilities adjacent to or near oil refineries. All plants are located within 10 miles of Martinez and are now 30+ years old. As a byproduct of petroleum refining, the value of coke is low, and combusting it for process heat or power is its highest use. The plants qualify as QFs due to their use of a "waste" material. The plants use fluidized bed technology, making either coke or torrefied wood an acceptable fuel.

Due to location, wood waste from forests would be as much as $60/BDT when delivered to a coke plant location, or $3.50/MMBTU. This relatively high delivered fuel cost is due to a large transportation component. Torrefied wood loses 10 percent of BTU value, raising fuel cost to $3.88/MMBTU, plus production and processing cost. Combustion efficiency would be equivalent to coke, so no economic advantage is realized. This is the rough equivalent of $60/MWH in fuel cost alone. Torrefied wood cannot be an economic replacement for coke nor would the power producer be competitive in the current electric marketplace.

In terms of replacement of Utah or New Mexico coal in the four traditional small coal plants in California, the economics are slightly better. Forest waste could likely be delivered to the two San Joaquin Valley plants for about $45-50/BDT, or $2.60-2.90/MMBTU. Torrefied wood would be $2.90-$3.22/MMBTU, plus processing cost. The problem for torrefied wood in this application is that these projects use fluidized bed technology, allowing the forest waste or agricultural waste to be utilized directly in these facilities with only modest de-rating – therefore, making the torrefaction process and expense unnecessary. This is also true of the two plants in San Bernardino County.

There are also a limited number of cement kilns in California that potentially could provide markets for torrefied word as a replacement for coal or other fuels. Unlike coal ash, however, biomass ash does not have the same pozzolanic properties sought by cement manufacturers, and so more detailed study would need to be done to determine market potential. Again, economics versus unprocessed materials would be a deterrent.

The bottom line is that no likely market for torrefied wood exists as a replacement for coal in California due to economics versus petroleum coke or unprocessed forest or agricultural waste. Torrefied wood may have a market elsewhere as a replacement fuel for "pulverized" coal plants, but the nearest such plants are north of Las Vegas, Nevada (due for closure by 2020) and near Carlin, Nevada – both outside economic haul distances. There appears to be no near term economic use for torrefied wood in California.

6.1.1.10 <u>Wood Pellets</u>

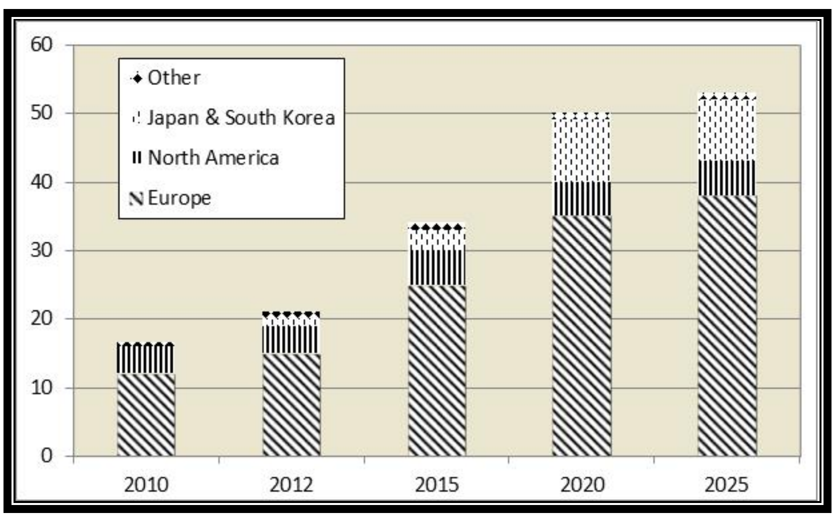
Wood pellets are a biomass fuel that is burned to heat buildings or co-fired with coal to generate electricity. In the Western U.S., wood pellets are generally manufactured from sawmill by-products such as sawdust and planer shavings. The advantages of those feedstocks are that: they are sometimes already dry (i.e., shavings); they are already in a size and form that requires little additional processing prior to pelletizing; and in some regions of the west, sawdust and to a lesser extent shavings have limited market value from other users. In contrast, roundwood as a feedstock requires extra costs for chipping/grinding and hammer milling the incoming stems into a form suitable for pelletizing. In addition, roundwood is typically purchased on a weight basis. About 10 to 15 percent of the weight of roundwood is bark, which is typically not used in the manufacture of pellets. Thus, the cost of the actual wood fiber is increased by the proportion of bark included. Finally, unless it comes from standing dead trees, roundwood has to be dried because its moisture content is too high for pelletizing.

The manufacturing process involves drying these wood residues to approximately 10 percent moisture content and then milling them to a uniform size. Next, the material is compressed with a die and roller to a density of about 40 pounds per cubic foot. The resulting pellet is cylindrical in shape and sized between 1.0 and 1.5 inches long and 1/4 to 5/16 inch in diameter. In the Southeastern U.S., where it is more cost effective to produce pulpwood, a number of pellet plants use clean chips from whole tree chip mills as their feedstock.

During the densification process, the temperature of the wood rises as the pressure inside the die increases. This causes the lignin in the wood to "plasticize". When the lignin reaches this state, the material is more easily extruded through a die, thereby becoming densified and forming a pellet shape. The extruded pellets are then cooled, which causes them to "set" in their final form. No added adhesives are used in the manufacturing process. Finished wood pellets are dense and durable, which means they can be economically transported long distances with little degradation. Finished pellets typically contain 6 to 8 percent moisture (by weight). The technology is well proven.

Wood pellets have two main uses. The first is for space heating, including residential, commercial, and industrial buildings. The second is for co-firing with coal in the production of electrical power. The global market for wood pellets has grown rapidly. In 2013, the global market for wood pellets was estimated to be 23.6 million metric tons. Since 2001, the size of the market has grown by an average of 21 percent annually. Of the consumption in 2013, 4.0 million metric tons was in North America, primarily for space heating. 1.0 million was utilized in Asia. Europe used 10.0 million for space heating and 9 million for co-firing. The market is forecast to grow to over 50 million metric tons by 2025 (see **Figure 6.3**).

Figure 6.3 – Forecasted Global Pellet Demand
(Millions of Metric Tons)



Source: Poyry & Wood Pellet Association of Canada

As shown in the figure, the North American market is forecast to be relatively stable due to its market being primarily for space heating. This is a disadvantage to prospective pellet producers in California since the largest markets for space heating are in more distant, colder climates and in the Northeastern U.S. where limited availability of natural gas means many homeowners opt for pellet heat over more costly propane and heating oil.

Also illustrated in **Figure 6.3** is that the Asian market is forecasted to be a significant part of the growth, with the main use being for co-firing. Up to this point, much of the demand from Asia has been satisfied from pellet manufacturers in Vietnam and from a relatively small amount of pellets exported from Canada and the Western U.S.

Many believe that further development of an Asian market will be an opportunity for wood pellet manufacturers on the U.S. and Canadian West Coast. However, several obstacles exist. First, there are a number of existing pellet manufacturers in British Columbia with access to low cost feedstocks (i.e., mill residues that have limited market value aside from use as pellet feedstock) and well established logistics, including networks for transporting pellets from the mill via rail and truck to port facilities, storage and handling infrastructure at the port, and ports with sufficient depth to accommodate large bulk carriers. Such world class pellet handling logistics in California are not well established. Similar issues exist in Oregon and Washington.

Second, the production of sawmill residues in California (sawdust and shavings) is much lower relative to other regions in the Pacific Northwest such as Oregon and Washington. BECK estimates that the mills in California produce about 200,000 bone dry tons of sawdust and shavings combined annually. The Sierra Pine particleboard plant in Martell, California has an annual capacity of about 166,000 MSF per year (3/4" basis). The average particleboard plant requires about 1.3 bone dry tons of feedstock per MSF. Thus, the Martell particleboard plant is likely to consume the majority of the sawdust and shavings produced in by California's sawmills. This in turn, means that access to a low cost supply of raw material for pellet manufacturing is limited. This is problematic from a low cost supply perspective since pellet plants producing pellets for export markets generally need to be capable of producing more than 150,000 tons of pellets per year to produce quantities large enough to interest foreign utility buyers and to achieve efficiencies of scale.

Third, while there may be ample supply of feedstock available from pulpwood, the economics of manufacturing pellets using pulpwood feedstock are less cost-effective than using mill by-products. This is because the full cost of harvesting and hauling the pulpwood must be borne by the pelleting operation. When mill residues are used, the cost of harvesting and hauling the material to a centralized location is "subsidized" by the sawmill. This difference is especially pronounced in California where the mountainous terrain makes pulpwood relatively expensive compared to pulpwood operations in the U.S. Southeast. For these reasons, BECK has determined that while pellets are a proven technology and the market is forecast to grow, other regions' producers will have a competitive advantage over California producers.

6.1.1.11 Potential Greenhouse Gas (GHG) Opportunities

It has become apparent that several emerging technologies for energy use from waste biomass will struggle to compete financially in existing markets unless they are able to monetize the GHG benefits of the technology. This review will examine existing law and regulation and speculate as to whether substantial benefits will be derived from these programs. The GHG programs investigated are:

1. California's Global Warming Solutions Act of 2006 (AB32), which establishes a goal of lowering 2020 GHG emissions to match 1990 levels.
2. California Air Resources Board (CARB) Low Carbon Fuel Standard (LCFS), which seeks to lower transportation carbon intensity (CI) 10 percent from 2010 levels by 2020.
3. The Federal Low Carbon Fuel Standard (Federal LCFS), which mandates levels of biofuels in transportation fuels through 2022.

AB32 covers up to 85 percent of California's total GHG emissions by focusing on sectors emitting more than 25,000 metric tons of CO_2e annually (MT CO_2e/year). During the first phase of the program (2013-14), the program focused on electric suppliers and CO_2 suppliers. During the second compliance period (2015-17), producers and suppliers of fuel oil, LPG, LNG and natural gas will be added. It will require roughly a 15 percent reduction in current GHG emissions in California by 2020 to return to 1990 levels.

The AB32 program operates as a cap and trade program, whereby most allowances are distributed to the covered entities, and those with excess allowances can trade them to those needing allowances. Some are held in reserves by CARB and auctioned. It is also possible to create additional allowances through such approved mechanisms as forestry projects and other forms of carbon capture and sequestration (CCS).

It appears that the recession of 2007-2011 has allowed California to meet its early goals for the program at modest cost. Electrical loads have dropped, meaning that utilities were easily able to meet early year targets. Auctions of credits have produced results with values at or only slightly above minimum sale prices of $10-12/MT CO_2e. The program demands that minimum bids increase by 5 percent annually plus the Consumer Price Index (CPI) amount from the previous years' auction reserve amount, so some growth in value will be realized.

It is hard to project what will happen to prices in the second and third compliance periods. The addition of other fuels this year and the return of modest amounts of electrical growth may drive prices higher. There is also a protocol being developed for biomass combustion of excess forest waste that might yield GHG tonnages for traditional biomass combustion to have to sell.

California LCFS – As stated earlier, the LCFS seeks to reduce the Carbon Intensity (CI) of transportation fuels by 10 percent of 2010 levels by 2020. This program has gotten off to a rocky start, and this form of measurement (CI) does not benefit from the recession. It was expected that the major reductions in CI would come from the inclusion of corn ethanol, cellulosic ethanol, natural gas, biodiesel and electricity into the transportation sector. While maximum amounts of corn ethanol are being used, only bio and renewable diesel among the other sectors are making substantial contributions, with electricity very minor and cellulosic ethanol non-existent.

Shortfalls in compliance are satisfied by the purchase of credits, which, like the AB32 program, are designed to cover the emission of 1MT of excess CO_2e. Credit prices during the 2012-13 program years averaged $57/MT$CO_2$e, a substantial amount. A successful lawsuit against the program in 2013 froze the advance of the program, however, and credit prices have plummeted to $25/MT today. In order to restart the program, the CARB must readopt the program with changes, which was supposed to happen in the Feb/March 2015 timeframe. The readoption will more accurately reflect the lack of availability of biofuels beyond corn ethanol and will lower interim reduction targets, but leave the 2020 reduction goal of 10 percent intact. This readoption will continue the advance of the program, but will likely moderate credit prices in the early years due to the lower targets.

The LCFS program is being harmonized with AB32 this year, and how that interplay will affect credit availability and prices is unknown. CARB has taken the value of a $100/MT credit to the fuel producer and estimates it is worth $0.56/gallon for cellulosic ethanol and $0.78/gallon for renewable diesel. Whether these prices will be obtained by 2020 is unknown, but certainly achievable. Since the credit limit increases annually, a $200/MT credit limit could cause the value to become significant.

Federal LCFS – The federal LCFS operates off a different principle. It mandates the amount of biofuel that must be added to U.S. transportation supplies by year, climaxing at 36 billion gallons/year in 2022. Of this amount, only 15 billion gallons can come from corn ethanol to protect food supplies. For supplies other than corn ethanol (2nd generation biofuels), a tax credit of $1.01/gallon is available to distributors.

Like the California LCFS, the federal LCFS has suffered from a lack of biofuels other than corn ethanol despite the mandate and tax credit. The Federal EPA, which administers the program, has been forced to lower early year projections and establish moderate penalty amounts. The outcome to date has been unsatisfactory for nearly all parties.

Transportation and Electric Fuel Future – At the state level, the mandates for lowering GHG emissions and transportation fuel carbon intensity extend only through 2020 via legislative action. Governor Brown's Executive Orders (S-3-05, B-16-12) extend the GHG reductions to 2050, with a goal of 80 percent less than 1990 levels, but this is not the same as legislative action. This goal is so aggressive, however, that if codified by legislative action, it would nearly assure a lucrative market for cellulosic ethanol and other biofuels, as well as a further raising of the electric Renewable Portfolio Standard (RPS) to perhaps 50 percent renewable power. With the ability to establish protocols for CCS projects, it is likely that some of the biomass products, such as biochar, will be able to monetize carbon benefits under these programs.

The federal LCFS has a very uncertain future, with the existing tax credits being allowed to expire. Bills have recently been introduced in Congress to eliminate the program, but would almost certainly be vetoed by the President. It is virtually certain that the current LCFS program will not be enhanced or extended by this Congress.

Bottom Line – With current programs extending only to 2020 and 2022, and credit values being modest to date, it is not possible to develop a project, beginning today, based on these markets. In the case of state programs, however, the chance for extension beyond 2020 would appear high.

One strategy for a project seeking to begin development today on the strength of current programs (SB 1122) would be to choose a reasonably well developed technology that could be modified later to produce additional amounts of biochar, for instance, as the benefits are codified and markets mature. In the case of a biomass electric project, a gasification/internal combustion engine project might be developed with the gasifier slightly oversized for the engine to allow for greater amounts of biochar to be produced later while still meeting electric output commitments.

Other technologies, such as pyrolysis oil, cellulosic ethanol and drop-in biofuels may need to wait for market opportunities to further clarify and develop, as well as for technological developments.

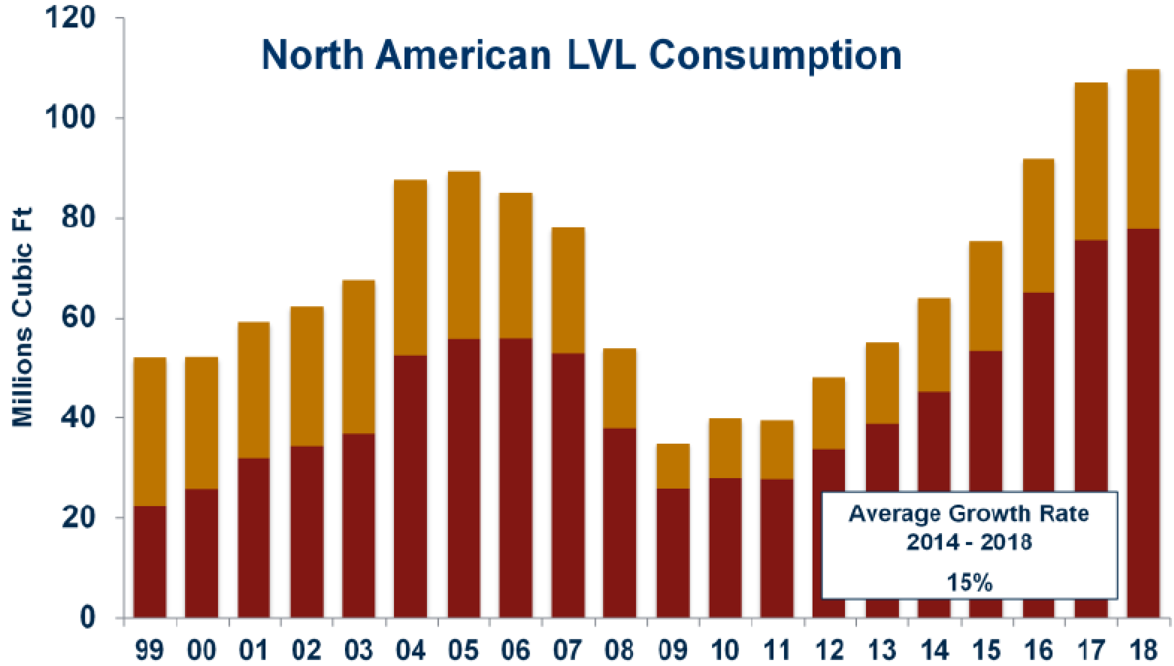
6.1.2 Traditional and Engineered Wood Products Technologies

6.1.2.1 LVL

LVL, or Laminated Veneer Lumber, is used in a variety of applications, but mostly in structural applications such as beams, headers, rimboard or edge-forming material. LVL is an engineered wood product and is produced by gluing many pieces of veneer together in a feathered layout with the grain oriented parallel. The veneer used in the production of LVL must be from logs that are Metriguard rated (high density) to ensure that the product will meet the design values.

The demand for LVL is highly sensitive to new housing construction. LVL is used for long-span multi-ply (1 ¾” thickness) beams and headers and is also used as flange on I-joists, another engineered wood product. Approximately 30 percent of the LVL produced is used as I-joist flange stock, with the remaining balance being used as beams and headers. As shown in **Figure 6.3**, FEA is projecting North American consumption of LVL to increase significantly, average 15 percent growth between 2014 and 2018.

Figure 6.3 – Historic and Projected North American Consumption of LVL (Cubic Feet millions)



LVL demand for I-joist is expected to increase in the future due to a shortage of 2 x 3 solid sawn lumbers. Only 5 percent of machine stress rated lumber is 2" x 3" in North America, yet it accounts for over 80 percent of the sawn lumber I-joists. The 2" x 3" MSR lumber is mostly manufactured in eastern Canada and made from black spruce. That source of supply is in doubt going forward.

LVL offers advantages over typical milled lumber. LVL is made under controlled specifications, making it stronger, straighter, and more uniform. LVL also lets defects in the wood be distributed in a way that is not detrimental to the finished product, thereby allowing the majority of the wood to be utilized.

LVL manufacturers must have third party certification, mostly through the APA, to ensure that their product meets the design values. These design values ensure that the product will not fail in structural applications. Daily quality control tests are standard for LVL, testing the modulus of elasticity, modulus of rupture and the tension. The APA also audits the quality control process monthly to ensure their third party certification.

The LVL market share and usage rates have grown since 2005. It is predicted that demand for LVL will reach all-time highs in 2017 as long as housing starts continue to increase. LVL has in excess of 50 percent of the total North American residential beam and header market and holds a dominant position in long-span beams and headers. There will be a need for added capacity to the LVL sector to meet the demand for beams and headers and I-joist flange stock.

At the moment, LVL producers are operating at approximately 65 percent capacity. However, if the housing starts continue to increase and the demand for LVL flange continues to increase, there could be a need for additional LVL capacity. This capacity likely will be added by existing LVL manufacturers or other forest products companies with access to veneer from their other operations. A veneer peeling operation that supplies an LVL operation with raw material is a likely possibility as well.

FEA estimates that LVL manufacturing cost is approximately $16.00 per cubic foot. Of that total the cost of wood fiber is about 75 percent. This compares to sales values per cubic foot of about $19.00 in 2014. FEA also estimates that tightening veneer supplies over through 2018 will drive up LVL production costs. LVL manufacturers operating in the U.S. West include Pacific Wood Laminates in Brookings, Oregon; Roseburg Forest Products in Roseburg, Oregon; Boise Cascade in White City, Oregon; and RedBuilt in Stayton, Oregon.

6.1.2.2 Fencing

Fencing lumber is produced at sawmills employing similar technology to that used for producing structural framing lumber, but with equipment configured specifically for efficiently producing fence boards. California timber species typically associated with fence boards include naturally durable wood such as redwood and incense cedar. White fir is also used to make fencing (though the total market for this product is much smaller), and unlike cedar or redwood, it is typically stained prior to being sold to the end user.

While some cedar and redwood manufacturers produce fencing products in combination with other exterior products such as siding or decking, the vast majority of fencing lumber is produced at operations specifically designed for fencing production.

Most fencing products are nominally 1” thick (actually 5/8”) by 4” or 6” wide, with lengths varying from 4’ to 8’. The most common and popular fencing lumber size is 1”x 6”x 6’. Redwood, cedar, and white fir fencing products are sold across North America, and especially in the U.S. West. Demand for fencing fluctuates over time, correlating positively with activity in the residential home construction and repair/remodeling sectors. The total market for wood fencing is large and robust, supporting numerous manufacturers across the West and South.

California is already home to several fencing producers, including Sierra Pacific Industries, so business opportunities for expanding fencing production in the state would most likely be determined by available log supply. While a typical fencing mill can utilize smaller diameter timber (as would be generated by thinning programs), larger logs are also needed as part of the overall supply in order to achieve production efficiency.

In the coastal region of California, adding fence board manufacturing capacity could improve markets for small diameter redwood logs derived from thinning projects. In the interior region of the state, impacts on forest thinning would likely be modest since incense cedar is typically a small proportion of the total forest.

6.1.2.3 Finger-jointed lumber

Finger-jointed lumber is produced for a variety of reasons. Finger-jointed lumber can be produced from short pieces of dimensional lumber to achieve desired dimensions. It can also be produced from dimensional lumber to achieve a higher grade. The defects, cutting them out, and finger jointing the two pieces of lumber together.

Finger-jointed dimensional lumber is accepted and utilized in the building and construction industry. It is accepted for use under all model building codes and is interchangeable with solid-sawn dimension lumber of the same size, grade and species as long as the lumber has been grade marked accordingly.

Finger-jointed lumber for which the end use is structural is commonly manufactured from lumber that has been seasoned to below 19 percent moisture content and is grade stamped “S-DRY” or “KD”. However, some finger-jointed products are manufactured from unseasoned lumber and are grade stamped “S-GRN”.

The lumber is assembled with a waterproof, exterior-type adhesive. Finger-jointed lumber has limitations on knot size and placement near joints is highly restrictive. Testing and quality control procedures are highly rigorous and must meet ASTM product standards.

Finger-jointed lumber is sold as lumber to be used in all structural applications and lumber to be used strictly as suds or for vertical use only. Finger-jointed lumber offers several advantages. It allows companies to utilize pieces of wood that would otherwise be discarded. Also, by using shorter pieces of lumber, the boards generally exhibit less warping and are stronger overall compared to ordinary studs. Finger-jointed lumber is a value added product in operations because it is a way to utilize more product from an existing sawmill.

6.1.2.4 Glulam

Glulam is an engineered wood product that involves gluing together pieces of timber. It is an innovative material that is used in construction in residential and commercial buildings. The product is a stress rated engineered wood beam composed of suitably selected and prepared pieces of wood in either a straight or curved form, with the grain of all pieces essentially parallel to the longitudinal axis of the member. Each piece of wood that makes up a glulam beam is referred to as a lamination and is bonded to other laminations with moisture-resistant adhesives.

The maximum thickness for each lamination in a beam is 50 mm or 2 in, and the laminations are typically made of standard 25 mm or 50 mm (nominal 1-2 inches) thick lumber. Requirements in North America state that the glulam beams must be made in an approved manufacturing plant. Glulam specs are limited by the size of the manufacturing operation and the capability to transport the product.

Some common species used in the production of glulam include Douglas-fir, Southern Pine, Hem-Fir and Spruce-Pine-Fir (SPF). While these are the most commonly used species, any species can be used as long as it has the proper physical and mechanical properties and acceptable gluing properties. Glulam is a versatile product that has many advantages over sawn timbers. These advantages include size capability, architectural effects, seasoning, variation of cross sections, grades and positive effect on the environment.

Glulam can be manufactured to be much larger than the trees from which the component lumber was sawn and has been used as a substitute for solid logs as utility poles. Glulam has been manufactured up to 140 feet long and up to 7 feet in depth. Glulam beams make it possible to produce large timbers from small diameter logs. Architectural effects include the bending/bowing of lumber during the manufacturing process to achieve a curved glulam beam. These finished products are very aesthetically pleasing and hard to replicate with other building materials.

A major selling point for glulam is that it has a much lower embodied energy than reinforced concrete and steel, making it an environmentally friendly alternative in smaller commercial structures. The embodied energy of glulam is six times less than the same suitable strength steel.

The manufacture of glulam must follow recognized national standards to justify the specified engineering design values. The quality of the wood and the adhesive bonds should demonstrate a balance in structural performance when glulam is manufactured properly. The manufacturing of glulam can be divided into four different procedures to complete the process – drying and grading the lumber, end jointing the lumber, face bonding and finishing, and fabrication. If a glulam beam is going to be susceptible to high moisture conditions or used as a utility pole, it also must be treated with a preservative.

Currently 24 companies are recognized by APA as being certified glulam manufacturers. Included among those manufacturers are Diversified Wood Resources, dba American Laminators/Duco Lam in Drain, Oregon; Riddle Laminators Inc., operating in Riddle, Oregon; Western Structures, LLC in Eugene, Oregon; and Rosboro in Springfield, Oregon. BECK is not aware of any plants currently operating in California.

6.1.2.5 Large Scale Sawmill

California is home to numerous industrial scale sawmill operations producing a variety of lumber products ranging from commodities (dimension and stud lumber) to specialty appearance grade products (pine shop and common boards, redwood siding, etc.) Sierra Pacific Industries (SPI) is by far the dominant company operating sawmills in the state. They are well established in both the state and industry and have significant timberland holdings to supply their sawmills with logs. The development of any new sawmill in California will be heavily influenced by the location of SPI’s timberland holdings and existing sawmills.

The technologies employed in these sawmills continue to evolve, but are generally mature and well-proven. Lumber manufacturers in California compete with producers from all over the world, and especially other parts of North America in end markets. One advantage California sawmills have is proximity to market **–** large population centers in Central and Southern California are some of the largest markets for lumber products in North America.

In general, lumber markets rise and fall with new home construction and repair/remodeling activity. This is especially true of structural lumber products, but it also applies to many types of specialty products.

The primary challenges facing lumber manufacturers in the state are a restrictive regulatory environment and limited access to timber. Access to timber is limited because of shortened and restricted logging seasons (relating back to regulatory and environmental issues) relative to those in other states, and because of constrained timber harvests on federal lands (which account for well over 50 percent of the states forestlands).

While there might be opportunities for new (i.e., “greenfield”) sawmill construction, there is likely even greater potential to expand production capacity at existing facilities, particularly where additional volumes of timber can be made available through thinning and forest health projects on federal forests.

In order to entice producers to expand existing facilities (through adding production hours/shifts or adding new equipment) or to build new sawmills, a consistent and secure/reliable supply of timber is essential within 50-75 miles of the facility. Because many federal timber harvest sales and projects have been subject to litigation, this has not been the case in recent years. That is, producers have been reluctant to invest in expanded lumber production capabilities based on potential supplies of timber from federal forests because that timber has not proven to be reliably and consistently available.

It is also worth noting that much of the timber available from thinning and forest health projects is small in diameter. Not all mills are currently equipped to efficiently process this material, and even for those that are, medium or large logs generally need to be a significant part of the total raw material supply in order for the operation to remain efficient and competitive.

6.1.2.6 MDF

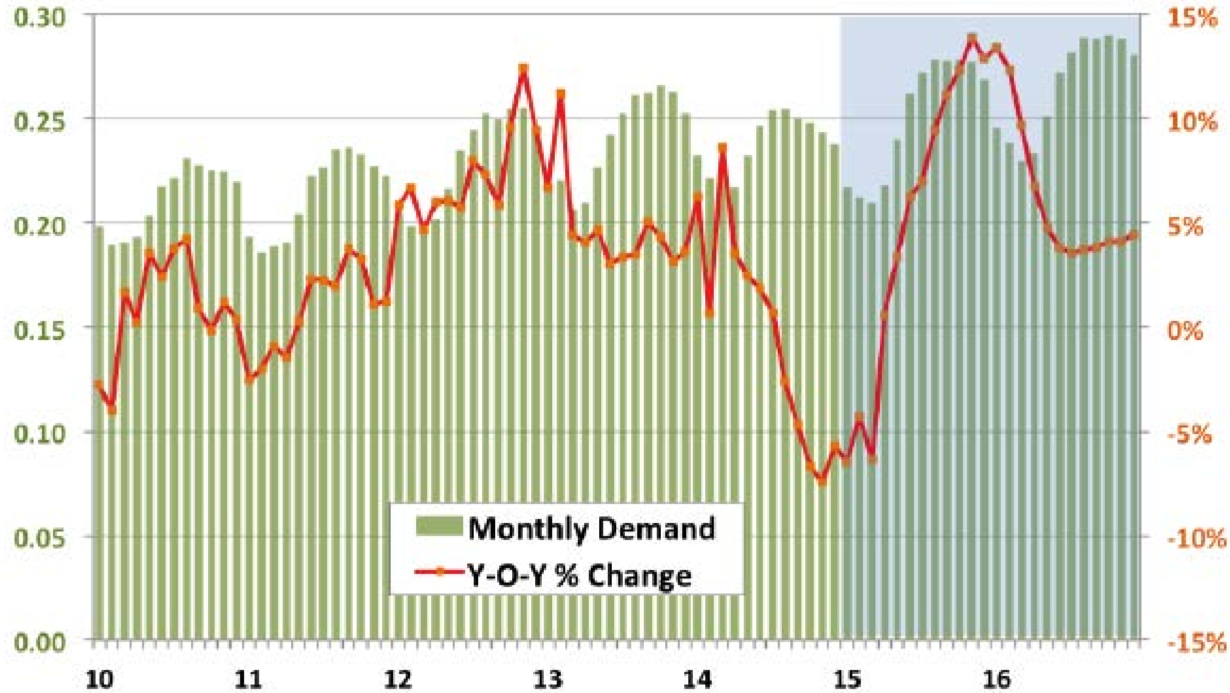
Medium density fiberboard (MDF) is a generic term for a panel primarily composed of wood that has been reduced in size to individual fibers or fiber bundles. Those fibers are combined with a synthetic resin and bonded together under heat and pressure. The panels are compressed to a density of 31-50 pounds per cubic foot or lower or higher for specific applications like door core or laminate flooring.

Additives may be introduced during manufacturing to improve certain properties. Because MDF can be cut or routed into a wide range of sizes and shapes, it is very versatile and used in a variety of applications. The surface of MDF is flat, smooth, uniform, dense, and free of knots and grain patterns, making finishing operations easy and consistent. The homogenous edge of standard MDF allows intricate and precise machining and finishing techniques. Some grades have a density profile with higher density on the face than in the core.

Furniture manufacturers are also embossing the surface with three-dimensional designs during the Decorative Surface laminating or finishing. Or cutting and routing pieces for trim and raised surface designs. Exterior grade MDF usually contains various borate additives toxic to termites, wood boring beetles, molds, and fungi.

MDF Demand – According to Forest Economic Advisors, North American MDF demand was 2.884 billion square feet BSF (3/4" basis) in 2014. It is expected to increase 5 percent in 2015 to 3.06 BSF (3/4" basis). The important near-term factor of a strengthening U.S. Dollar is expected to increase Canadian exports of MDF to the U.S. to an estimated 350 MSF (3/4" basis) in 2015. The stronger dollar may also allow producers in South America to export product to the U.S. Historic and projected North American MDF demand is shown in **Figure 6.5**.

Figure 6.5 – North American MDF Demand BSF (3/4" Basis)



MDF Supply – North American MDF shipments totaled 2.10 BSF (3/4" basis) in 2014, and North American shipments are expected to increase to 2.24 BSF (3/4" basis) in 2015 according to Forest Economic Advisors. In addition, off shore imports contributed a little over 800 MSF (3/4" basis) to the supply in 2014. Off shore imports are expected to contribute about 865,000 MSF (3/4" basis) in 2015. No new production facilities are expected in the foreseeable future. The demand capacity ratio for 2014 was estimated to be 69 percent and is forecast to increase to 74 percent in 2015.

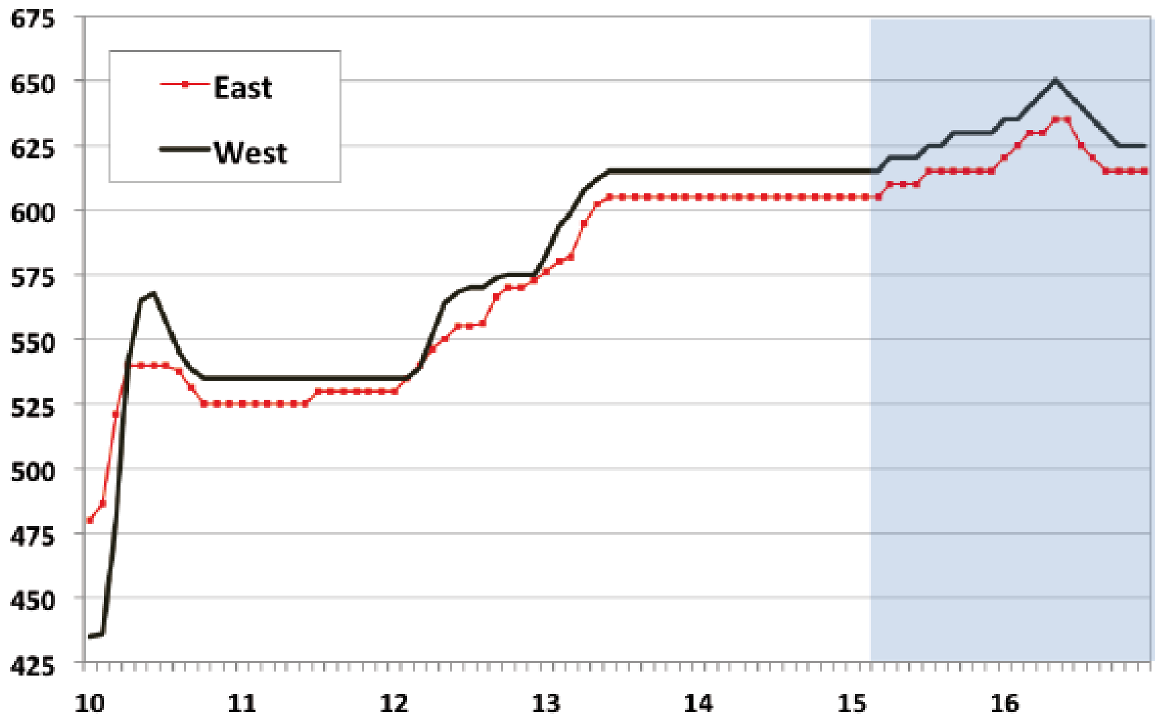
In California, the last remaining MDF plant, Pacific MDF Products in Rocklin, California has been closed and dismantled. Thus, there is currently no MDF production in California. However, there are MDF plants operating in Eugene, Medford, and Klamath Falls, Oregon, as listed in **Table 6.2**.

Table 6.2 – Production Capacity of Particleboard Plants in Oregon

Company	Location	Annual Production Capacity (MSF ¾" basis)
Flakeboard/Arauco	Eugene, OR	75,000
Sierra Pine	Medford, OR	125,000
Jeld Wen	Klamath Falls, OR	20,000

Figure 6.6 displays historic and projected MDF pricing in North America as reported by FEA. As illustrated, the prices have been relatively stable during the last two years. Also note that the pricing difference between east and west is much less pronounced for MDF than was seen with particleboard.

Figure 6.6 – Historic and Projected MDF Pricing
($/MSF 3/4" Basis FOB Mill)



In BECK's judgment, MDF is not a likely prospect for development in California, with the key reason being that North American MDF production capacity relative to demand is high. In addition, nearly 25 percent of the North American demand is being supplied by offshore producers with modern cost-effective plants, and the offshore supply is expected to increase as the U.S. dollar strengthens. Thus, any MDF plant developed in California would face difficult competition from established domestic and off shore producers.

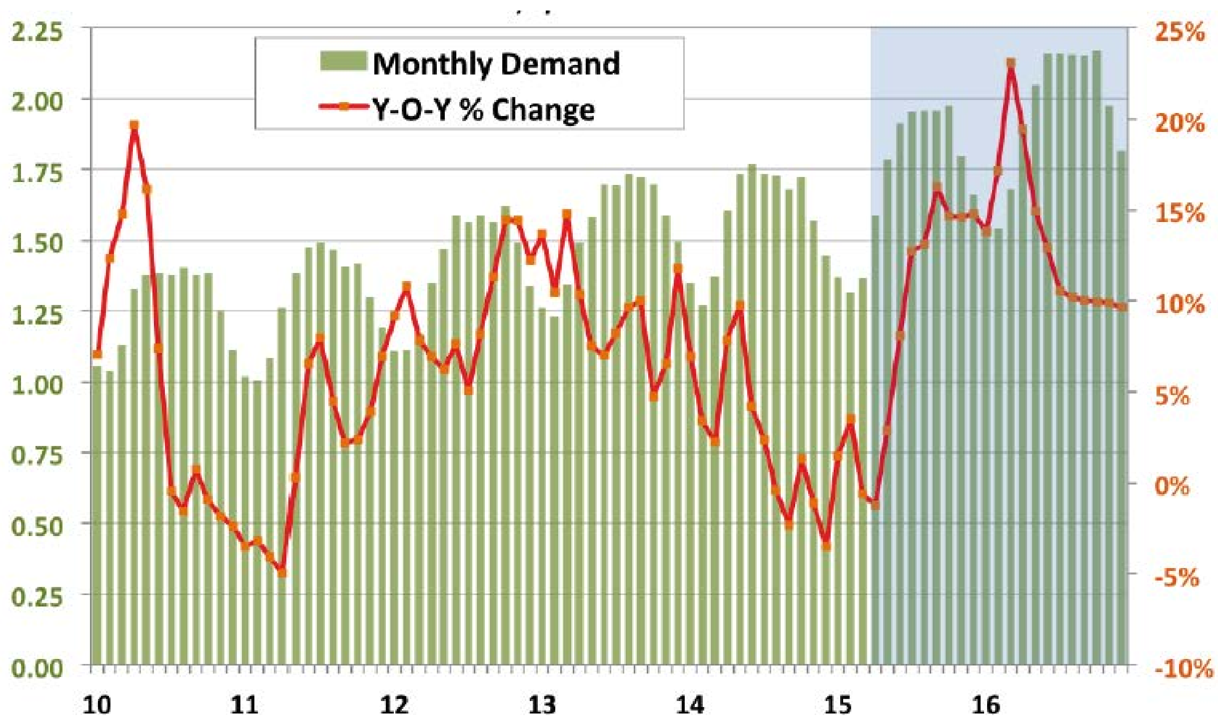
6.1.2.7 Oriented Strand Board (OSB)

OSB is an engineered wood product made using large flakes or "strands" of wood combined with resin to produce panels of various dimensions. OSB has been manufactured on a commercial scale since the 1970s, and the technology is mature and well proven. Structurally rated OSB can be manufactured from a wide variety of species, and most facilities use pulpwood logs as a raw material source. The logs are debarked and processed at a flaker (similar to a chipper). Flakes are dried, mixed with resin, formed into panel shape, and pressed at high temperature.

Panels are designed for specific structural properties, with primary uses being in exterior sheathing for walls and roofs. However, some specialty applications exist as well. North American market demand for OSB is tied very closely to construction, and specifically, residential construction.

North American OSB production expanded rapidly starting in the 1980s, eclipsing plywood production in 2000 and peaking in 2005 at approximately 25 billion square feet (3/8" basis). Forest Economic Advisors estimates 2015 production at 21 billion square feet (3/8" basis) see **Figure 6.7.**

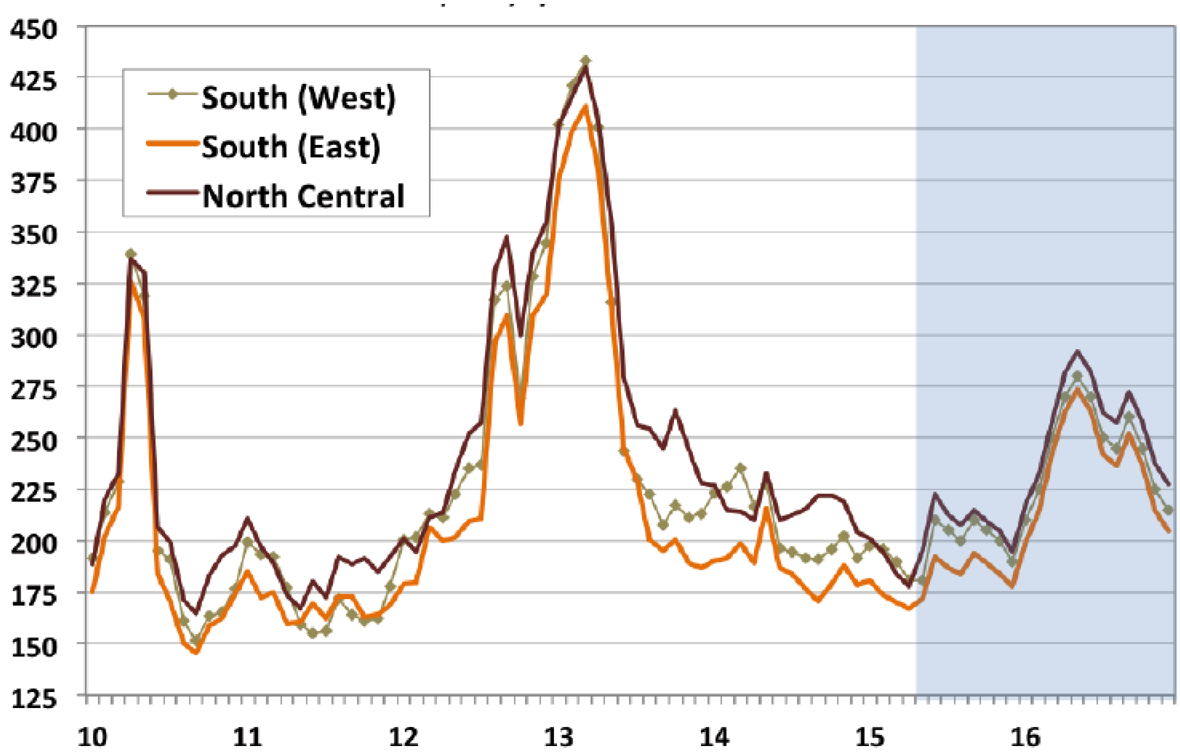
Figure 6.7 – North American OSB Demand BSF (3/8" basis)



While OSB manufacturing facilities are in operation across Canada and the U.S. South and Midwest, there are no OSB producers in the West. A reason for this is that pulpwood, the primary feedstock for most OSB mills, is more expensive on a delivered basis due to the rugged terrain of the West. However, this situation creates a potential transportation cost advantage for a possible OSB producer located in California. The vast majority of OSB production is located 1,500 or more miles away from major markets in Central and Southern California.

Figure 6.8 (source FEA) illustrates the volatility of OSB pricing. Relatively minor changes in the level of new home construction can cause price spikes if additional manufacturing capacity is not brought online. Similarly, over production can cause periods of depressed pricing.

Figure 6.8 – Historic and Projected OSB Prices ($/MSF 7/16" basis)



BECK estimates that an OSB mill located in Central or Northern California could expect to enjoy a transportation cost advantage of approximately $25 per thousand square feet (3/8" basis) compared to operations in Texas, Arkansas, and Louisiana. Even if the operation is small in scale, leading to higher manufacturing costs and having higher delivered log costs, a new facility located in Central or Northern California should be able to remain competitive with other producers. **Table 6.3** compares the estimated economics of OSB production in both regions.

Table 6.3 – Relative Economics of California Based and AR-LA-TX OSB Producers

$ per MSF (3/8" basis)	N. CA	AR-LA-TX
Delivered panel value (Southern Cal)	$240.00	$240.00
Transportation to market	$15.00	$40.00
FOB mill sales value	**$225.00**	**$200.00**
Wood ($/ton)	$35.00	$30.00
Recovery (M3/8 per ton)	0.62	0.62
Wood (panel basis)	$56.45	$48.39
Wax, resin	$30.61	$30.61
Manufacturing costs	$106.25	$96.25
Total costs	**$193.31**	**$175.25**
Pretax profit	**$31.69**	**$24.75**

One significant advantage of OSB production in terms of increasing markets for small diameter logs from thinning and forest health treatments is that OSB mills typically can utilize logs ranging from 2”-3” in diameter on the small end to 20” or larger at the large end. Thus, for a typical thinning project, 100 percent of the timber harvested could be sent to a single destination with no log sorting or merchandizing being necessary and a much greater proportion of the total volume being utilized compared to other major log consumers such as sawmills or veneer producers.

The major hurdle for developing an OSB plant in California is timber supply. Plants producing 350-450 million square feet (3/8” basis) on an annual basis are considered small operations. At a panel recovery level of 0.62 tons per thousand square feet (3/8” basis), approximately 550,000 to 725,000 tons of raw material would be needed per year. This demand level is similar in scale to some of California’s largest sawmill operations. Even though there is little current utilization of pulpwood in California, it may be difficult to identify a single location that would be able to reliably supply that significant a volume of logs over the long term. One option for increasing the raw material supply to an OSB mill would be to locate the facility near one or more sawmills. Then, machines that currently produce pulp chips at sawmills could be converted to produce OSB flakes. Depending on the conversion completed at each sawmill, 20 percent or more of the total weight of logs sawn at the facility would be available as byproduct flakes for OSB production.

6.1.2.8 Parallam

Parallam or Parallel Strand Lumber (PSL) is used in structural applications for columns, beams, and headers and has been a product since the mid-1980s. Parallam uses a process of bonding together long thin strands of wood that have been cut from veneer. The thin wood strands are laid in a parallel formation and bonded together with adhesive. The length-to-thickness ratio of the strands in PSL is approximately 300.

Parallam was invented, developed, commercialized and patented by Weyerhaeuser. Parallam is the world's only commercially manufactured and marketed parallel strand lumber product. The product is similar to LVL and glulam and is used for beam and header applications where high bending strength is needed. The product is also frequently used as load-bearing columns.

Parallam is a substitute product for other structural composite lumber such as LVL or glulam. With the LVL demand being so high, and only one company producing Parallam, the product does not have high potential for growth in the structural composites market.

6.1.2.9 Particleboard

Particleboard is a panel product made by compressing small particles of wood (generally sawdust or shavings) while simultaneously bonding them with an adhesive. There are many variations in the size and geometry of the particles, the amount and type of resin used, and the density to which the panels are pressed. All, however, are typically aimed at offering a less expensive, denser, and more uniform material than solid wood that can be used where a relatively smooth surface at low cost is required.

The ideal particle for strength and dimensional stability is a thin flake of uniform thickness with a high length-to-thickness ratio. However, most particleboard plants rely on mill residues as a feedstock and, therefore, have limited ability to control particle size and geometry. This affects particleboard manufacturing in several important ways. First, the smaller pieces (fines) tend to absorb a disproportionate amount of resin and can lead to overuse of resin if not controlled. On the other hand, using smaller, finer pieces on the outer faces of the panels and thicker, bigger pieces in the core saves resin and allows for creating a smooth surface profile for subsequent laminating while saving weight and cost in the core.

The vast majority of particleboard is surface laminated with a decorative exterior. The most common decorative surfaces laminated to composite panels are:

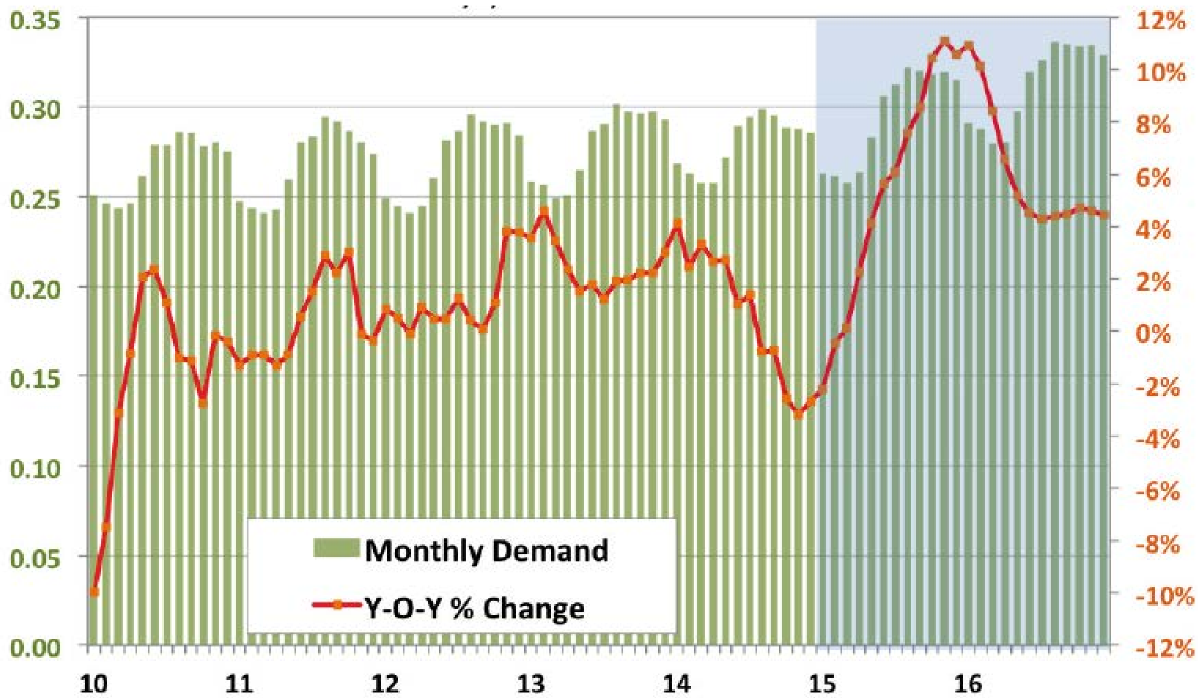
- Wood veneer
- High Pressure Laminates
- Decorative Melamine Overlays (TFM – the largest volume surface technology)
- Vinyl Overlays
- Thermo-foil
- Low Basis Weight and Top Coated Paper

- Coatings (liquid or powder coatings)

The laminating process is a secondary process, meaning the panel itself is manufactured in a board mill, and the panel is surface laminated in either a secondary process at the board mill or at the OEM or fabricator. Though it is denser than conventional wood, it is the lightest and weakest type of composite panel. A major particleboard disadvantage is limited tolerance to changes in moisture content.

Particleboard Demand – North American particleboard demand for 2014 totaled 3.36 billion square feet BSF (3/4" basis). North American demand in 2015 is expected to reach 3.54 BSF (3/4" basis) according to Forest Economic Advisors. See **Figure 6.9**.

Figure 6.9 – North American Particleboard Demand BSF (¾" Basis)



Source: Forest Economic Advisors

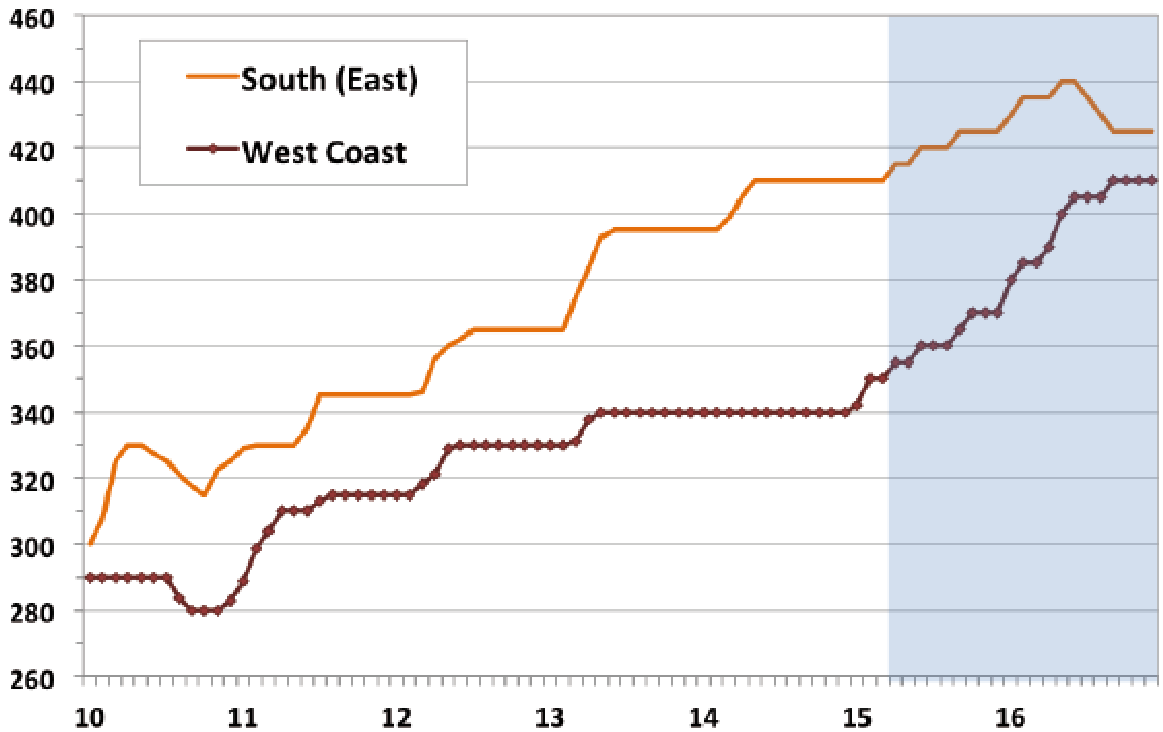
Particleboard Supply – The North American particleboard production capacity is estimated to be 4.7 BSF (3/4" basis). Thus, the demand to capacity ratio is estimated to be about 73 percent for 2015. In other words, demand in North America is only about 73 percent of the existing manufacturing capacity. The demand to capacity ratio is not expected to increase significantly in the foreseeable future. Of that capacity, there is only one plant in California, the Sierra Pine plant at Martell, which has an annual production capacity of 166,000 MSF (3/4" basis). In addition, there are significant particleboard manufacturing operations in Oregon, including Roseburg Forest Products in Dillard, Collins in Klamath Falls, Arauco in Albany, and Boise in LaGrande. **Table 6.4** shows the company, location, and production capacity of these plants in Oregon.

Table 6.4 – Production Capacity of Particleboard Plants in Oregon

Company	Location	Annual Production Capacity MSF (¾" basis)
Roseburg Forest Products	Dillard, OR	350,000
Collins	Klamath Falls, OR	135,000
Arauco	Albany, OR	250,000
Boise	LaGrande, OR	166,000

Particleboard Pricing – Figure 6.10 displays the historic and projected particleboard prices for the U.S. South (East) and the U.S. West Coast. The prices shown are dollars per MSF (3/4" basis) and are fob plant. Note that prices in the West tend to be 10 to 20 percent lower than prices in the South (East).

Figure 6.10 – Historic and Projected Particleboard Prices (\$/MSF (¾" Basis) FOB Mill)



In BECK's judgment, particleboard is not a likely prospect for development in California. A key reason for this is that this industry relies heavily on by-products (sawdust and shavings) of sawmills as a feedstock. The average particleboard plant requires about 1.35 bone dry tons of raw material to produce 1,000 square feet of particleboard (3/4" basis). This means that the plant in Martell requires nearly 225,000 bone dry tons of raw material annually. This compares to the estimated total annual production of sawdust and shavings in the State of California of 370,000 bone dry tons. Thus, the supply of sawdust and shavings for an additional particleboard plant in the state is not currently available.

Another reason is that the North American particleboard production capacity relative to demand is high. This situation causes significant competition and easily leads to weak pricing when mills try to increase production beyond demand levels. The demand to capacity ratio for particleboard production has been hovering in the high 60 to low 70 percent range for several years, and it is not expected to improve significantly in the near future. Thus, any new plant built in California would have to overcome the established production systems and distribution networks of existing producers.

6.1.2.10 Plywood

Plywood panels are composed of individual layers of veneer, with alternating layers having their wood grain oriented at 90 angles to one another. The manufacturing process consists of applying glue to individual sheets/layers of veneer, laying them up in panel form, and pressing the panels with a heated press. Most softwood plywood manufacturers use phenol formaldehyde resin. Plywood has been produced at commercial scale for many decades and the technology is well proven and mature.

Historically, plywood was used extensively in exterior sheathing for home construction in North America, but OSB has taken over the majority of this market, leading to the shuttering of numerous North American plywood mills. While exterior sheathing is still an important product for some plywood manufacturers, flooring/underlayment, concrete form, and other specialty products now make up a much larger percentage of plywood production than they did 20 years ago. Total North American plywood production is estimated to be approximately 11 billion square feet per year (3/8” basis), with mills expected to operate at 89 percent of capacity, on average, according to Forest Economic Advisors.

In many cases plywood layup lines are located at the same facility as veneer peeling lines, but not always. Steam is typically used for heating the plywood presses, so co-location with veneer peeling and/or other users of steam, such as a biomass power plant, can be beneficial.

The addition of plywood manufacturing capacity could add value to small and medium sized timber in California, but only if coupled with additional veneer production. The current nearest plywood producing operations are located in Southern Oregon, including Boise in Medford, Murphy Company in Rogue River, Roseburg Forest Products in both Coquille and Riddle, Swanson in Glendale, and Timber Products Company in Grants Pass.

6.1.2.11 Post and Pole

Post and pole manufacturers are consumers of small diameter roundwood. According to a study conducted by the U.S. Forest Service and the University of Montana, the post and pole industry in 12 western U.S. states produced an estimated 60,000,000 linear feet of treated and untreated posts and poles of varying diameters in 2001 (the most recent data available). Of that amount, about one-third was produced in Montana and one-quarter in Oregon, the first and second leading post and pole producing states, respectively. At the time of the study, California had only 1 post and pole manufacturer, but had three post and pole chemical treating plants. Also at the time of the study, it was estimated that annual production was only about 50 percent of installed capacity.

The estimated value of the material produced in 2001 was $83 million (includes both treated and untreated). The common post and pole market segments include fencing, agriculture/vineyards, highway signage and guard rails, utility poles, roundwood furniture, and structural and architectural accents. The agricultural and vineyard market in California is significant.

Although a number of species are commonly used in the western U.S. for the manufacture of posts and poles, Lodgepole pine is a preferred species because the bark is thin, which makes for relatively easy processing. In addition, the lodgepole trees tend to grow in densely stocked stands, which results in trees with smaller branches (small knots), straight form, and very little taper and defects. This in turn, results in posts and poles with desirable characteristics. In addition, lodgepole pine trees tend to have a large sapwood area, allowing the chemical preservative to be readily absorbed by this species. The vast majority of producers receive the raw material in the form of delimbed, tree length stems. Several, however, receive material in cut-to-length pieces.

As shown in **Table 6.5**, post and pole products are allocated into four general post and pole size classes. The second column in **Table 6.5** shows the percent of overall production that occurred in each size class (Source: U.S. Forest Service and University of Montana).

Table 6.5 – Size Distribution of Post and Pole Production in the Western U.S.

Post and Pole Size Class (inches)	Percent of Production
2.0 to 2.9	13
3.0 to 4.9	56
5.0 to 6.9	26
7.0 and larger	5
Total	**100**

To increase the utility of posts and poles, they are often treated with chemical preservatives to improve decay resistance. The common treatment methods include: (1) pressure treatment in a vacuum, (2) butt-treatment – dipping the large end of the post in a chemical bath, and (3) dipping the whole post in a chemical bath. **Table 6.6** shows the average value of treated and untreated poles by diameter class. (Source: U.S. Forest Service and University of Montana). As illustrated in **Table 6.6**, chemical treatment increases the value of the post and pole by an average of about 10 cents per lineal foot (excluding the smallest size category, which is typically only a relatively small part of overall production). According to interviews of existing post and pole manufacturers, the ability to provide both treated and untreated posts and poles across a variety of size classes is a key aspect of operating a viable post and pole business. Unfortunately, developing and operating a treatment plant requires a relatively large capital investment and has the burden of meeting a number of environmental permitting regulations.

Table 6.6 – 2001 FOB Mill Value of Treated and Untreated Posts and Poles by Size Class ($ Per Lineal Foot)

Diameter Class	Treated	Untreated
2.0 to 2.9	0.36	0.33
3.0 to 4.9	0.60	0.49
5.0 to 6.9	1.12	1.02
7.0 and larger	1.84	1.75

For a time during the early 2000s there was intense competition from Canadian manufacturers who were exporting their products into the U.S. The level of competition decreased later in the decade, but could again increase as U.S. dollar strengthens. Access to raw material supply is an issue though for many Canadian post and pole producers.

There are two types of processes used to produce posts and poles. The first, called “peeling”, removes the bark and a small amount of wood fiber from the tree steam along the natural taper of the log. Thus, one end of the peeled post/pole will have a larger diameter than the other end. The second process is called doweling. With this method, the stem is passed through a set of rotating knives that chip and/or shave away the wood fiber to produce a doweled post/pole that has a fixed diameter along its entire length. Doweling systems tend to run faster than peeling systems.

In the U.S. West, post and pole plants produce approximately 1,200 pieces per day with an average length of 8 feet. This translates into producing 300,000 pieces per year. With regard to raw material, the average plant requires about 20,000 to 25,000 green tons of logs per year. A significant volume of the incoming raw material becomes downfall in the form of bark and/or chips/shavings. Thus, access to markets for selling these by-products is a key factor for post and pole producers.

The capital investment required for a typical plant ranges between $750,000 and $1.5 million, depending on the scale of the facility and the level of automation desired from the equipment. For example, some low capital mills buck the tree length stems by hand, while others use tracked excavators equipped with processing heads to buck and sort the pieces in the log yard. Still others use a log merchandising line to buck the tree length stems into post/pole lengths. All three options require differing levels of capital investment. A typical post and pole facility has 5 to 6 hourly laborers per shift, including an operator for cutting pieces to length, 1 to 2 forklift operators, a peeler operator, and a handler for sorting peeled poles into bundles by size/length class and for packaging the finished bundles.

California is likely the largest market for post and pole material where it is consumed in the agriculture, orchard, and vineyard industries. The critical issues in assessing this option include identifying adequate supplies of raw material; estimating the capital expense for the required equipment, site, etc.; estimating the ongoing operating expenses; and identifying the nearby markets for post and poles in California. Any production operation located in California will have a significant transportation cost advantage to the California market over other post and pole producers located in Oregon, Washington, Idaho, Montana, and Western Canada.

6.1.2.12 Semi-Mobile Sawmill

Because a significant portion of the total cost of producing lumber is associated with hauling logs from the forest to the sawmill, mobile sawmills are sometimes used to reduce or eliminate this cost. Mobile sawmills also have the advantage of moving from one region to another where timber may be available in the short term, but not for long enough to justify the major capital expense of a full scale industrial sawmill complex.

While mobile sawmills may have the advantage of reduced log hauling costs and reduced log supply requirements, there are also disadvantages to this model. In general, processing speed and efficiency are lower, leading to high manufacturing costs. Because mobile mills do not have kiln drying and lumber surfacing on site, product lines are limited to rough, green lumber markets (unless there are drying and surfacing facilities available somewhere in the region). Also, byproduct markets (chips, sawdust, bark) may be limited in these areas because there has not historically been sawmilling capacity.

Vaagen Bros. is the only known company who has operated an industrial scale (i.e., greater than 10 million board feet of annual production) mobile sawmill in recent years. Vaagen acquired a mobile HewSaw machine several years ago and operated it in Eager, AZ for approximately two years before the local supply of logs forced its closure. BECK interviewed Vaagen staff regarding the requirements of operating such a mill in the state of California. Details are listed below.

Log supply:

- Diameter range: 5” to 12”
- Log consumption – 15-20 million board feet (Eastside Scribner scale) per year on one shift, or about 20 truckloads per 8 hours of operation
- Minimum log supply at one location – approximately 3 years or 50-60 million board feet within a 75 mile radius.
- Small ponderosa pine is feasible but the least desirable. Douglas fir, white fir, hemlock, and other species are preferable
- Average delivered log cost of less than $30 per ton (lumber market dependent)

Mill site requirements:

- 25 acres of relatively level ground (minimum)
- 3 phase power
- Water supply

6.1.2.13 Shingles

Shingles are thin, tapered pieces of wood that are used on roofs and walls of structures to provide protection from the weather. Wood shingles are typically made from redwood and cedar. Cedar and redwood shingles add an appealing, aesthetic appearance to homes, as well as providing natural resistance to insects and UV light.

These shingles provide a very high level of protection and have a unique look that is appealing to consumers looking for a specific style. While it is time-intensive to produce cedar shingles, no expensive, fossil-fuel based process is required. This makes the shingles attractive to many consumers because they are environmentally friendly and they have a low carbon footprint. The shingles are also completely recyclable after their lifetime.

Like most other wood products, cedar and redwood shingles come in different sizes and grades. Cedar shingles are produced to three main sizes and four main grades. Depending on the quality of the wood and the way it is sawn, the shingles are assessed with a grade from 1-4.

Cedar and redwood shingles are mainly made from salvaged wood fiber. Wood that is left over from logging work or windblown material is salvaged for the production of cedar shingles. Therefore, they may not be the best product option when forest management is a main objective. Also, cedar and redwood shingles are manufactured from the heartwood portion a tree stem, which relative to the sapwood in the outer perimeter of a tree stem, contains higher levels of chemicals that contribute to the decay resistance of the wood. Old growth and large diameter second growth trees provide the most heartwood and the best natural decay resistance because of the extractives (chemicals) in the heartwood.

For this screening matrix, small diameter logs and the products which provide the best chance at managing the forests utilizing these small diameter logs are the focus. Because of the need for large diameter logs in the production of shingles, it may be best to focus on other products that can better utilize small diameter logs.

6.1.2.14 Small Scale Sawmill

Small sawmill operations employing fewer than 10 employees and processing a few million board feet of logs per year (or less) are in business in a variety of locations across North America. Most of these mills specialize in custom processing of logs or production of high value niche lumber/solid wood products.

These sawmills have the advantage of having very low capital cost requirements and, in some cases, are mobile, having the ability to move from one source of logs to another. In order to remain viable businesses, these mills typically rely on large logs that can yield high valued specialty lumber products. Small logs are very low productivity/high cost for these operations and do not yield the high value products needed by this business model. Because of their reliance on larger diameter logs and their relatively low annual log volume consumption, expanding the number of small scale sawmills in California is not likely to significantly improve the economics associated with forest thinning or forest health treatments for federal forests.

6.1.2.15 Veneer

Peeling veneer from softwood logs is the first step in producing raw materials for a variety of the technologies being evaluated for this project, including plywood, LVL, Parallam, and I-joists. Typically, veneer is peeled in thicknesses up to 1/10".

Veneer has been commercially produced from softwood logs for many decades, so the technology is well established and mature. The key components of a successful veneer peeling operation are a log resource that is well matched to the desired veneer products, peeling equipment matched to the log resource, and good management.

While nearly all softwood veneer was historically laid up into plywood panels, the rise of LVL (laminated veneer lumber) and the use of LVL in I-joist production has led to a significant percentage of veneer being diverted into non-plywood applications.

In evaluating opportunities for expanding the use of small diameter timber from California's federal forests, it is important to consider the log supply requirements of a viable veneer peeling operation. Regarding log size, a number of operations in Oregon, Washington, and British Columbia have been successfully processing small logs with an average diameter of approximately 8 inches and a minimum diameter of 6 inches. Depending on factors such as the taper of the log, this translates to an average tree DBH of approximately 11 inches or larger. Total annual log volume requirements for a new, modern operation would likely be in the range of 15-20 million board feet (Eastside Scribner scale) for a single shift operation, or 30-40 million board feet for a 2 shift operation.

In the U.S. West, Douglas fir is the favored species used for veneer (and especially LVL veneer) due to its superior strength properties. However, other western species such as hemlock, true firs (white fir, grand fir, etc.), and ponderosa pine are commonly peeled.

While fire salvaged logs can be peeled for veneer production, they need to be harvested relatively quickly and not allowed to dry out over the course of many months or years.

Veneer peeling operations utilize steam for conditioning of the veneer blocks before peeling, as well as a heat source for veneer drying. Therefore, establishment of a veneer plant in conjunction with a biomass power plant would allow for a combined heat and power or cogeneration project.

California is currently home to two industrial scale veneer peeling operations, including Timber Products Company in Yreka and Roseburg Forest Products in Weed. Both operations ship the majority of their production to plywood and LVL manufacturing facilities in Oregon.

6.1.2.16 Wooden I-joists

I-Joists are an engineered wood product designed to eliminate problems that occur with conventional wood joists. I-joists are manufactured using LVL or solid sawn flange and cutting a groove on the tangential side of the top and bottom pieces of flange. A piece of OSB is than inserted between the two, perpendicular to the flange creating a product that mimics a capital I when looking straight forward, hence the term I-Joist. I-Joists will not bow, crown, twist, cup, check or split as would a dimensional piece of lumber, and they carry heavy loads with less lumber required than dimensional solid wood.

I-joists are engineered to provide strength where it is needed most, which is at the top and bottom of the joist. Loads on joists act downward, yet wood fibers are stressed horizontally, along the length of the joist. As the joist bends, this causes the top fiber to be in compression and the bottom fibers to be in tension.

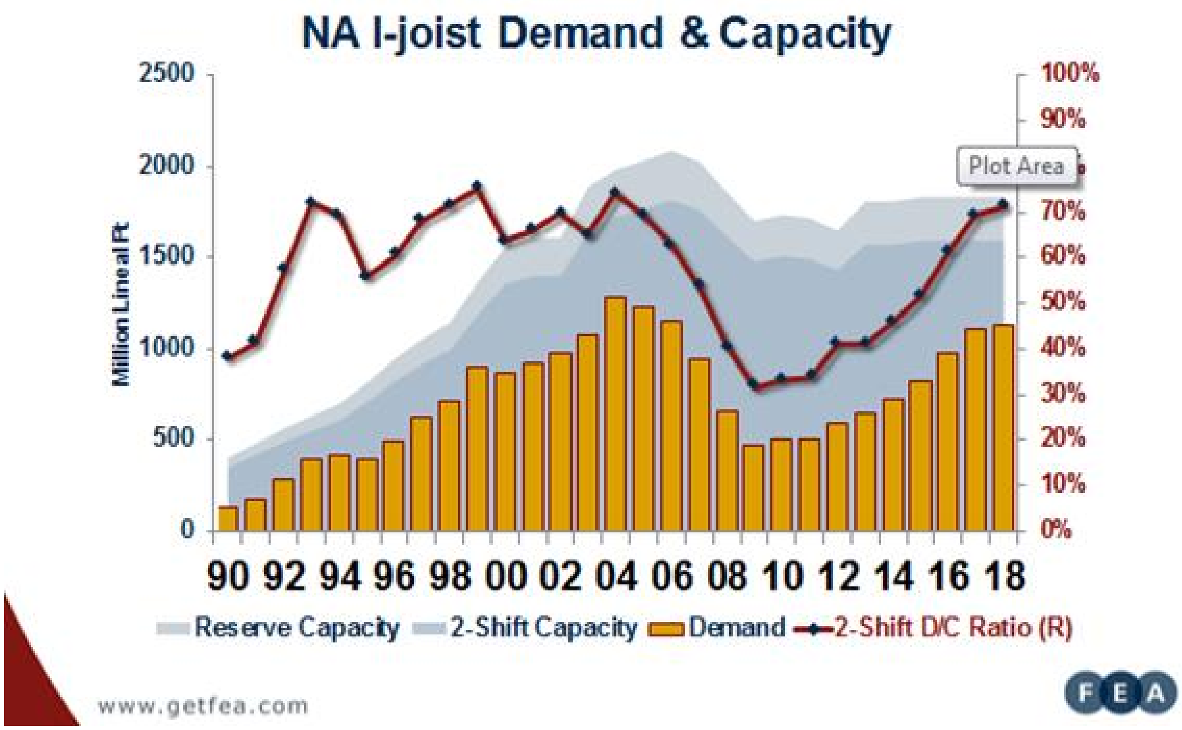
The top and bottom edges are moving in different directions while the fiber in the middle of the joist is neither being compressed nor pulled apart. This area is known as the neutral axis and is where the I-shape takes advantage of this fact as I-joists do not waste fiber where it is not needed. I-joists offer advantages over solid sawn dimensional lumber by having design flexibility with increased span potential, improving stiffness, increasing strength and being more consistent in appearance and performance. They also utilize more wood fiber, which results in less waste.

The costs associated with producing I-joists are primarily driven by wood costs of OSB web stock and either MSR lumber or LVL flange stock. From 2008-2012, wood costs averaged 79 percent of the total variable costs for lumber flange I-joists and 87 percent of LVL flange I-joists.

Forecasts for the demand of I-joists call for an increase of 10 percent by 2018. I-joist manufacturers are currently running at a 2-shift demand/capacity ratio of approximately 60-70 percent. Therefore, the major I-joist manufacturers have more than enough capacity to supply the forecasted demand. (See **Figure 6.11**)

With the 2-shift demand/capacity ratio from existing producers being between 60-70 percent, the I-joist market will be served for the next few years by existing producers. For this project, I-joists do not appear to be a viable product. It is relatively mature, with many established manufacturers.

Figure 6.11 – North American I-joists Demand and Capacity



Source: FEA

6.1.3 By-Products Using Technologies

6.1.3.1 Air Filtration Media

A potential use for woody biomass is bio-filtration, a process that uses wood chips as a way to filter malodorous air. The wood chips have the ability to filter out the unpleasant odor by utilizing bacteria growing in the chips as a medium. The types of facilities that have the need for air filtration include sewage treatment plants and waste processing facilities.

Bio-filtration requires a bed of biomass chips to be sorted into cells, with the bed reaching approximately 8 feet in height. The amount of cells required depends on how much air needs to be filtered. Each cell holds approximately 2,000 cubic yards of wood chips. Such filters may require large use of a large area. For example, a facility capable of handling more than 200,000 cubic feet of air per minute may require the use of an area much larger than a football field.

A challenge to operating these systems is maintaining the biomass material at the optimal moisture content, so that bacteria growing on the moist wood have the ability to filter the odor by essentially "feeding" on the odor. This bio-filtration method reduces volatile organic content (VOC) emissions more effectively than inorganic filtration media. These filters have an effective life of five years before they have to be replaced with new biomass.

The market for this type of bio-filtration product, as briefly stated in the first paragraph of this section, would be sewage treatment plants and waste processing facilities. However, any type of operation that produces odors that are unpleasant and are noticeable could benefit by using this product. Plum Creek Timber Company's MDF plant in Columbia Falls, Montana reportedly invested $9.5 million to install a biofilter to decrease pollution emitted by the manufacturing process. That solution was apparently lower cost than the alternative of using natural gas to incinerate the pollutants.

Chip size specification for bio-filtration is in the 3-6 inch range, while no chip less than 1 inch is acceptable for this product. Experience has shown that screened, ground biomass is ideal since it's stringy nature provides pathways for air flow. The preferred species for the wood chips are pine and fir, with eucalyptus and redwood being unfavorable species because of their inability to support the proper bacteria. After the wood chips' life cycle as air filtration media is completed, they are composted. (See **Figure 6.12**)

With the parameter for chip size being 3-6 inches, the best feedstock for this product is logs that can be chipped to the specified sizes. Small diameter logs from a thinning operation would fit the feedstock profile for an air filtration process.

Published information about the value of chips used for air filtration is difficult to find. Anecdotally, however, it has been reported biomass air filtration facilities may pay as much as $40 per cubic yard delivered. There are roughly 4 cubic yards per ton. Therefore, this price translates into a value of about $160 per green ton. This is a very high price relative to other biomass utilization technologies. It is not clear if this price would apply across all air filtration applications or if lower cost alternatives using other materials would be utilized for very large applications. This concept could represent a potential source of income for a business that had other markets for materials from a grinding operation. Other markets for the grinder material that do not meet the specifications for filtration media could include hog fuel, planting mix medium, or landscaping material.

Figure 6.12 – Wood Chips as Air Filtration

6.1.3.2 Animal Bedding

Wood shavings are commonly used in association with various animals and livestock where it serves as both a bedding material and an absorbent for manure and urine. Among large animals it is most commonly used as bedding/absorbent material for horse stalls. It is also used to a lesser extent in dairy operations. In the U.S. South, shavings are commonly used as a bedding/absorbent material in poultry operations. Shavings are also used (but in smaller quantities) for small caged pet animals and lab animals. Finally, several shavings manufacturers in the Inland West region recently reported that a market had developed among the oil and gas industry in the region for using shavings as an absorbent at drilling sites.

BECK is not aware of any published information regarding the size of the animal bedding market. However, for prior project work, BECK employed U.S. Agricultural Census data to estimate the horse population in the Western U.S. That information was then used to infer the size of the animal bedding market for horses. As shown in **Table 6.7**, it is estimated that there were a little over 844,000 horses in those states as of the 2012 Census. Assuming that 15 percent of those horses are bedded in a stable and that each of those horses uses one bag of shavings every other day, it translates into an annual usage of over 23.1 million bags of shavings per year.

An industry standard is that each bag of shavings is compressed to 3 cubic feet in volume. Assuming a compressed shavings expansion factor of 2.5, there is a total of 1.2 cubic feet of solid wood per bag. This, in turn, translates to about 33 pounds of wood per bag. Assuming a weight of 33 pounds per bag (at 10 percent moisture content), the estimated size of the bagged shavings in tons is about 380,000 tons per year. During the recent economic downturn, the horse population declined considerably as people had less disposable income and keeping horses is generally viewed as a luxury item. This recession negatively affected the market for animal bedding. However, as the economy recovers, horse ownership is expected to increase and, therefore, grow the market for animal bedding.

Table 6.7 – Western U.S. Horse Population (2012)

State	Horse Population
AZ	92,394
CA	142,555
CO	110,360
ID	61,439
NM	50,723
NV	22,464
MT	97,921
OR	70,427
UT	58,979
WA	64,616
WY	72,461
Total	**844,339**

Historically, bagged wood shavings have been produced from the by-products of sawmilling operations. A number of sawmills in the Pacific Northwest and Western Canada have installed bagging machines in order to produce shavings for sale as animal bedding. However, during the economic downturn, many of those sawmills operated at severely reduced rates, leading to limited supplies of planer shavings for animal bedding, which caused the development of machines that can convert small diameter roundwood directly into wood shavings. The shavings resulting from these machines tend to be “fluffier” and more absorbent than planer shavings produced at sawmills. Thus, the shavings machine shavings are often preferred by horse owners.

At the retail level, a bag of shavings typically sells for about $5.00 to $6.00. At the fob mill level, BECK estimates that bags are often sold in the $2.75 to $3.00 per bag range. BECK estimates that a roundwood to wood shavings operation would consume about 20,000 to 25,000 green tons of feedstock per year and would produce about 500,000 bags of shavings per year (each bag compressed to 3 cubic feet). The estimated capital cost for such a facility would be about $2.5 million.

Given the large market for bagged shavings in California, BECK believes that this business opportunity is worthy of a more detailed analysis. Key issues for consideration include identification of: the market size within a reasonable transportation distance of the plant; the fob mill sales price; and other competing bagged shavings producers, including the existing American Wood Fibers operation in Jamestown, CA.

6.1.3.3 Hardboard

Hardboard has applications as a paneling and siding product as well as an array of other uses. It can be utilized for furniture components, molded door skins, wall paneling, underlayment and perforated boards. Hardboard is a composite panel manufactured primarily from cellulose fibers consolidated under heat and pressure in a hot press to a density of at least 31 lbs. per cubic foot.

The inter-fiber bond is primarily achieved through the action of the lignin mechanism. Other materials may be added during manufacture to improve certain properties such as stiffness, hardness, finishing, resistance to abrasion and moisture, as well as to increase strength, durability and utility. Hardboard panels can be laminated with paper overlays, plastic laminates and veneers to enhance appearance.

The benefit of hardboard is the product’s ability to utilize byproducts of solid sawn wood items, such as wood chips and board trimmings. Hardboard is made almost wholly from wood, but does not need logs or round wood. The wood chips are converted to fibers which are permanently bonded under heat and pressure into a panel. The fibers are combined with natural and synthetic binders and other additives that improve certain properties.

Another advantage is the uniformity of the product, as hardboard has no knots or naturally occurring defects. Hardboard also holds paint extremely well when used in siding applications and resists marring, scuffing and abrasion.

Different hardboards have different fiber formulations, accounting for characteristic variations in product density, thickness and finishing properties for almost unlimited uses. Hardboard is a mature product that has been around for over 50 years, but its use is in decline. Therefore, for this project it is best to look at other up and coming wood technologies.

Presently, there are two hardboard plants east of the Mississippi serving the western United States hardboard markets. More hardboard plants have closed down in the last 50 years than have opened as the demand for hardboard is dwindling and being replaced by other products.

6.1.3.4 Liquid Filtration Media

One of the main ways that woody biomass is used in liquid filtration is in the form of biochar filtering water. Biochars are highly porous reactive materials that are the product of pyrolysis of biomass and can be a low-cost alternative to activated carbon as a liquid filtration medium. The research on biochar has shown that the filtration method has a high capacity to remove heavy metals from solutions.

Biochar filtration works through adsorption rather than absorption. Adsorption is the adhesion to the medium of atoms, ions or molecules from liquids. Contaminants in the water diffuse into the pores of biochar (the process of absorption) where they bind to char surfaces (the process of adsorption). Biochar has a high surface area and is highly porous, providing many reactive sites for the attachment of dissolved compounds.

6.1.3.5 Whole Log Chipping

Whole Log Chipping (WLC) refers to the production of pulp chips (see **Figure 6.13**) from whole logs. Please note that producing pulp chips from whole logs is a different process than producing chips from the by-products of sawmilling (mill residual chips or MRCs).

Figure 6.13 – Pulp Chips Which Are Used For Making Paper

Several key differences exist between chips made from each process. First, WLC chips tend to be of higher quality than MRCs. This is because pulp mills need chips that are consistently sized, which is a characteristic of WLC chips. MRCs chips, on the other hand, tend to have more fines and pin chips (chips that are too long and narrow). In other words, MRCs tend to be less consistent in size and, therefore, are generally lower quality than WLC chips.

Second, the availability of each type of chip depends on factors that are more or less independent of each other. The availability of MRCs depends on the production of lumber. Thus, during times when sawmills are operating at reduced rates because of limited demand for lumber, MRCs availability drops. WLC chips, on the other hand, can be produced independently from lumber manufacturing. Thus, their availability is a function of factors such as timber supply, stumpage costs, and logging activity. For example, according to information published in the North American Wood Fiber Review, historically pulp and paper mills in the Pacific Northwest have acquired about 30 percent of their raw material from WLCs. However, at times over the last several years, when lumber production has been at historic lows, WLC chips have supplied more than 50 percent of the chips consumed at pulp and paper mills. It is also worth noting that pulp and paper demand is largely tied to global economic conditions as opposed to lumber demand, which is linked largely to the state of the U.S. housing market. Thus, the business cycle of the pulp and paper industry is not necessarily in sync with that of the sawmilling industry.

The third key difference is that MRCs are historically a lower cost raw material than WLC chips. The main reason for this is that it simply costs more to harvest trees, transport them to a chipper, debark the trees, chip the trees, and finally transport the chips to a consumer. MRCs, in contrast, only require chipping and transport. In many cases, the cost of collecting the material is allocated to the cost of the lumber being produced rather than the chips being manufactured from the sawmilling by-products.

Pulp and paper mills are a key market for pulp chips. There are no pulp and paper mills operating in California. Thus, there are no nearby pulp and paper markets. However, a pulp chip export dock was recently developed in Humboldt Bay, California by Green Diamond. It has the capacity to service large ocean going bulk carriers. However, a current slowdown of chip exports at the facility has been caused by sand filling in the channel between Humboldt Bay and the open ocean. This situation has prevented any ships from entering the chip export terminal. A dredging vessel has been requested to remedy the situation, but BECK's understanding is that there are very limited dredging vessels available on the entire U.S. West Coast. It is not known how long it will take to remedy the situation

The facility in Humboldt Bay is similar to the chip export facility operated by Roseburg Forest Products (RFP) in Coos Bay, Oregon. RFP has developed markets for pulp chips in Japan and to a lesser extent in China. The volume exported varies from year-to-year, but has been as much as 1.5 million bone dry tons per year. A chip export dock in Eureka has been developed to provide an outlet for the mill residual chips of the sawmills in the region. The capacity of that facility could be increased if WLC were also included in the mix.

WLC chips can be produced from either a stationary plant that would have a log handling and bucking system for sorting higher value saw logs from the chip logs, a drum debarker for removing bark from the logs prior to chipping, and motors powered by electricity. This equipment configuration is referred to as “stationary”. It is common for such plants in the U.S. South to produce 400,000 to 500,000 green tons of chips annually (200,000 to 250,000 bone dry tons). Low cost power is a key element for cost effective stationary WLC operations. The capital cost for such operations typically ranges between $3 and $5 million, depending mainly on the amount of log handling equipment needed and the extent to which used equipment could be located for certain parts of the operation.

A second chipping plant configuration is a mobile chipper that would be operated at logging sites. The mobile chipping plant configuration is a much simpler design – a single machine, powered by diesel, debarks and chips whole logs. This equipment configuration is referred to as “mobile”. The required support equipment includes a wheeled log loader for feeding logs to the chipper’s log transfers, a chipper, a screener, and a front end loader for moving bark away from the chipper and loading hog fuel into trucks. The front end loader may also load chips into chip vans, but this would normally be done by blowing chips from the chipper directly into vans. A typical capital cost for this type of operation is $1.5 to $2.0 million. Such an operation could produce about 75,000 bone dry tons of chips annually.

6.1.3.6 Wood Plastic Composites

Wood Plastic composites (WPCs) are made from a mixture of thermoplastic polymers and small wood particles, with the ratio of thermoplastic polymers to small wood particles being roughly 50:50. The wood and thermoplastics are blended together above the melting temperature of the thermoplastic polymers and then further processed to make a variety of WPC products.

WPCs can be manufactured in a variety of colors, shapes and sizes and with different surface textures. WPCs have a variety of applications that include windows, door frames, interior panels in cars, railings, fences, landscaping timbers, cladding and siding, park benches, molding and furniture. The most common WPC product is decking lumber.

Wood Plastic Composites offer a number of potential advantages over standard solid wood; however maintenance of the product is still required. The presence of wood in the plastic matrix can result in a stiffer and lower cost material then if plastic were used alone. This is because the compression properties of WPCs are superior to those of normal solid wood fiber when it is under a load applied perpendicular to the grain.

Moisture absorption and biological attack is also slowed down because of the plastic, making the maintenance of WPCs less involved than solid wood. WPCs will also not warp, splinter or check. Where plastic may have been used before, the addition of wood can reduce the “carbon footprint” of plastics because less fossil energy and material are required to make the final product.

Particle geometry of the wood is important in the manufacturing process of WPCs, with the wood used being in the form of dry particles with a powdery consistency, known as “wood flour." The raw material for producing WPCs comes as wood waste from other processes and is in the form of sawdust and planer shavings. Therefore, size reduction and classification are necessary steps to break down the feedstock into the preferred size and shape.

pine, maple and oak are the three most common species used to produce commercial WPCs, and as is the case with many different wood products, regional availability and cost are key factors in species selection. Many different species have been used to manufacture WPCs in a lab setting, and it was concluded that wood species is not an important variable.

Any fiber source that is readily available and inexpensive is generally preferred. One interesting finding from the research is that bark can be successfully utilized to extrude WPCs. Bark content as high as 25 percent can be included in the wood flour without significantly compromising the mechanical properties.

Approximate capital cost for this type of operation ranges from $5 million for a lower producing facility to $50 million for a high production facility. The size of the facility depends on different variables, including market size and feedstock availability. The approximate feedstock delivered economic target price is $200- $300/BDT for wood flour (already processed to desired geometry) or $50/BDT for dry clean wood less than 3" in size.

6.1.4 Other Forest Products Technologies

6.1.4.1 Anaerobic Digestion

Anaerobic digestion of woody biomass happens when the wood is exposed to certain bacteria in the absence of oxygen and under other controlled conditions. Anaerobic digestion of woody biomass produces biogas, which consists of methane, carbon dioxide and traces of other gases. The equipment needed for this process is a digester.

This biogas can be used directly as a fuel in a combined heat and power gas engine or upgraded to natural gas-quality bio methane. The digestate that is left over from the anaerobic digestion can be utilized as a fertilizer. In most cases, anaerobic digestion is implemented to manage waste of another process.

Biogas and digestate are the two outputs from anaerobic digestion. Both can be further processed or utilized to produce secondary outputs. In addition to being used as a natural gas substitute or a transportation fuel, biogas can also be used for producing electricity and heat. The digestate may be further processed to produce liquor that can be used as a liquid fertilizer or processed into a fibrous material, which can be processed into compost.

The potential markets include: compost for the digestate and heat/electricity generation for the methane. However, to use the methane for electricity generation a power sales agreement and thermal sales agreement are required.

One of the concerns with anaerobic digestion is the ability to be economically feasible because of low natural gas prices. Therefore, the costs involved with operating an anaerobic digester are higher than what an electricity company would want to pay for electricity produced. Compost that is produced as an output from anaerobic digestion has market potential as a soul amendment and in the agricultural sector.

The other concern is that anaerobic digestion has a variety of feed stocks that can include corn stover, wheat straw, fallen tree leaves, manure and yard waste. Woody biomass used as a feedstock in anaerobic digestion often requires pretreatment. A woody biomass anaerobic digestion operation would seem to work best when complimenting agricultural or food waste streams. Anaerobic digestion operations are more typically found in conjunction with agricultural operations.

With natural gas prices being low, an anaerobic digestion operation has a low probability of being economical on its own. If subsidies are available for the implementation of an anaerobic digester, the operation could be feasible.

6.1.4.2 Biochar

Biochar is a high carbon charcoal produced by using a pyrolysis method. The resulting biochar, if produced in a low temperature process, may contain about 50 percent of the original carbon in the wood. Since wood is typically 50 percent carbon, the resulting biochar will have about 25 percent of the weight of the original dry biomass. The biochar will be roughly 85 percent carbon.

The process of producing biochar is exothermic (i.e., releases heat), producing syngas, bio oils and heat in excess of the amount of energy required by the pyrolysis process. The process of biochar production consumes only about 15 percent of the total energy output available from the feedstock material.

A variety of kiln and closed vessel processes can be used to produce biochar, including microwaves. Gasification may be used, but the higher temperature will result in the yield of biochar being only about 20 percent of the original carbon.

Biochar can be used as a soil amendment, improving yields of various crops. It can be used to elevate pH, add low levels of nutrients, and increase water retention. In this regard, it is similar to the well-established practice of spreading biomass ash on agricultural fields in California.

The major selling point of biochar is that it is quite stable and can be used to sequester carbon in the ground if buried. In addition, buried biochar can also reduce emissions of soil N_20 and methane, further enhancing its carbon sequestration benefits.

Since the preservation of biomass carbon during processing removes carbon BTUs from the other products, its use as an energy source is degraded. In order to be an improvement on existing uses of biomass for "energy only" production, the carbon sequestration benefits must outweigh the lost energy benefits on an economic basis. The one reference that quoted economics stated that carbon prices would need to exceed $37/ton in 2007 dollars (approximately $40/ton today) in order for a combined biochar/energy production system to be economically feasible.

The key issues facing a proposed biochar installation today using forest biomass would appear to be the following:

1. There are far cheaper high volume biomass sources than forest waste, including municipal solid waste, sewage sludge, manures, and agricultural waste, that would be used before processing forest waste to produce biochar. These materials actually currently have a tipping fee associated with their disposal.
2. Currently, no protocol is approved for the use of biochar as a form of carbon sequestration in either California or globally, making it impossible to monetize the carbon sequestration benefits.
3. Current carbon market values in California are about \$11/ton of CO_2, only about 1/4 of the amount estimated to be necessary for an economic venture.
4. While biochar can be sold for high values per pound in small quantities today, that is a very small market that could be overwhelmed by the introduction of a couple of major producers. Larger markets, such as being a substitution for commercial fertilizers on agricultural lands, would require a dramatically lower price since up to 50 tons of biochar will be required per acre.

The following points comprise a high-level set of economics for a project in California today. Prepared by BECK using the metrics listed above, it includes:

- Wood waste cost = \$40/BDT
- Carbon quantity in incoming wood – 0.5 tons/BDT carbon remaining in biochar – 0.25 tons/BDT of incoming wood
- Tons of CO_2/ton carbon = 3.67
- Tons CO_2 in biochar = 0.92tons/ton incoming wood
- Value of CO_2 offset (2014) = \$11/ton
- Biochar contribution to economics = \$10.12/ton of incoming wood
- Biochar contribution = 25 percent of cost of incoming wood

6.1.4.3 Cross-Laminated Timber (CLT)

Cross-Laminated Timber (CLT) is a relatively new engineered wood product made from dimensional lumber. Similar to the basic concept of plywood, in which plies of veneer have the wood grain in each layer oriented perpendicular to the adjacent layer, CLT is made of 3 to 9 layers of dimensional lumber with each layer of lumber oriented so that the wood grain is perpendicular to the adjacent layer. Also similar to plywood, the layers of lumber are bound together using an adhesive. The adhesive is applied to the wide faces of the lumber and sometimes to the narrow faces.

CLT Panel Dimensions – The dimensions of CLT panels vary with the manufacturer and the application. In general, however, the thickness of the lumber used to make up the CLT panel varies between 5/8 and 2.0 inches. The width of the lumber used varies from 2.5 to 9.5 inches.

CLT panels are typically 8 to 10 feet wide, 40 feet long, and 4.5 to 20 inches thick. Since the length of the CLT panel is longer than normal lumber lengths, lumber to be used in a CLT application is finger-jointed to the desired length using a structural adhesive. CLT is normally produced with an odd number of layers (e.g., three, five, seven, or nine), with the resulting panel being a massive structural element that can be used as a prefabricated wall, floor, or roof element (see **Figure 6.14**). The lumber in the outer layers of the panel is typically oriented vertically so that the grain of the lumber in those plies is parallel to the force of gravity.

Figure 6.14 – CLT Panel Configuration

CLT Manufacturing Process – The primary component of CLT manufacturing is lumber, which must be kiln dried to 12 percent moisture (+ or – 3 percent). As described in the prior section, dimension lumber (2" nominal thickness) is a common feedstock. Thus, the development of a CLT plant would serve as another market for existing lumber producers. Alternately, a new sawmill could be developed with its output being dedicated primarily to providing feedstock for a co-located CLT manufacturing facility. The second key ingredient in the process is adhesive. The common adhesives used to laminate the plies (or lamella) include polyurethane, melamine and phenolic resins.

The basic processing sequence involves: 1) lumber selection; 2) lumber grouping by grade/thickness/width; 3) finger-jointing to produce lumber of the required length for maximizing CLT press utilization; 4) cutting the finger jointed lumber to length (i.e., to produce a 10' x 40' panel – cutting the appropriate number of 40 foot pieces and 10 foot pieces); 5) CLT panel layup; 6) CLT panel pressing; 7) CLT panel final sizing (i.e., surface sanding and final trimming to length and width); 8) CLT panel machining (e.g., cutting service channels and window and door openings); and 8) packaging for shipment. Transporting large panels could be a limiting factor.

Many of the steps in the process can be automated, but some of the existing plants in North America have taken a lower capital/higher labor approach and use manpower for several of the functions. The most time consuming aspect of the process is laying up the panels, which can take 15 minutes to 60 minutes. There is a window of time for the panel lay-up to occur because the adhesive will start to set. However, the amount of time for panel lay-up can be adjusted by changing the characteristics of the adhesive. The presses used in the process are typically hydraulically powered, but may also be vacuum presses. The final sizing and cutting of the panel typically is completed by using a large Computer Numerically Controlled (CNC) router/saw. An issue for the industry is standardizing whether the resulting CLT panels can be visually strength rated; rated using a formula incorporating panel dimensions, adhesive type, and species; or rated using non-destructive testing of the individual panels.

CLT Construction Advantages – The advantages associated with constructing buildings and other structures from CLT panels are numerous. First, the cross-laminating process provides increased dimensional stability relative to lumber. This allows for the prefabrication of long, wide floor slabs and long single-story walls. Cross-laminating also provides relatively high in-plane and out-of-plane strength and stiffness properties, which gives the material two-way action capabilities similar to a reinforced concrete slab. The seismic performance of CLT is also frequently cited as an advantage relative to other building materials. This may be especially important for the California market. The environmental footprint of CLT is often touted as a benefit when compared to similar steel or concrete building systems. This includes wood being a sustainable and renewable building material. Building with CLT also offers advantages in the speed of construction, which translates into cost savings. CLT has been adopted in the 2015 International Building Code (IBC), which paves the way for broader use. However, there still needs to be code adoption by local municipalities. Woodworks, a program of the Wood Products Council – a cooperative venture of major North American wood associations and government agencies, is actively working to advance acceptance of CLT into national, state, and local building codes.

Market Opportunity – The CLT market opportunity in the U.S. for 2015 was estimated to be about 0.9 to 2.7 billion board feet. The estimate was based on the assumption that CLT would penetrate between 5 and 15 percent in annual new residential and nonresidential construction of structures between 1 and 10 stories tall. If that estimate is accurate, it represents a market that is 3 to 10 times the estimated capacity of the global CLT industry. In terms of dollars, the market value is estimated to be between $1.44 billion and $4.32 billion ($19.32 per cubic foot) for the value of the CLT material alone. There are currently three CLT manufacturers in North America (two in Canada and one in the U.S.) The U.S. manufacturer, SmartLam in Columbia Falls, Montana, is currently producing CLT panels that are used in non-building structure applications (e.g., rigging mats for the oil and gas industry and utility mats for construction, etc.)

6.1.4.4 <u>Emerging Bioproducts</u>

For many years, government agencies and entrepreneurs have worked to develop various bioproducts that can replace traditional petrochemicals. These products run the gamut from cleaning supplies to lubricants, preservatives, and agricultural materials. Despite the wide range of products, a unifying factor is that all claim to be more benign, sustainable and climate friendly. However, virtually without exception, these products, despite decades of development in some cases, are not being mass marketed today. This phenomenon will be discussed in this section of the report.

Clearly, if bioproducts could be developed on a large scale, California would represent both a major product market as well as a potential manufacturing hub because of the wide variety and quantity of biomass materials. .

One of the key hurdles to development of bioproducts has been the lack of an objective authoritative body which can, cost effectively, certify the attributes of the bioproduct against its petrochemical equivalent. While it is possible to assure the public of the "greenness" of the product, it is difficult to show that its properties equal or exceed that of its petrochemical equivalent. Absent such an objective comparison, Purchasing Agents and even individual consumers will continue to buy what they know works.

Equally as important as lack of certification, has been the cost of alternative products versus the petrochemical equivalent. Of necessity, the bioproduct is produced in small batches in plants having only a modest capital cost. The plants are typically constructed with grant funds or on an all equity basis since they cannot meet the demands of banks for debt financing. These smaller production plants mean that the retail sales prices of the products are typically more expensive than their petrochemical equivalent.

Surveys have shown that consumers will pay more for a "green" product so long as they are not dissatisfied with its performance. However, that greater price has a limit, and that limit seems to be a price premium of only 10-15 percent over traditional products. One of the largest tests of green premiums is the electric market, where virtually every consumer is offered one or more choices of green electricity. Despite heavy consumer funded marketing campaigns, these programs rarely have a significant penetration when the consumer is required to pay more than 10-15 percent above the cost of traditional sources of electricity.

Another price related issue is that a bioproduct opportunity that looks exceptionally promising versus $10/MMBTU for wholesale natural gas can be wiped out by an extended period of $3/MMBTU gas. Since both oil and natural gas have been incredibly volatile in the last decade (and are at modest levels currently), it is virtually impossible to develop competing bioproducts in this context.

Bioproduct markets can clearly be established by government edict, either at the state or federal level, and this has been done in the past. These programs have not demonstrated sustainability, however, as they typically include a price cap (e.g., 10 percent more than conventional products) or are summarily ignored because of the extra work involved in sourcing alternative products. People/agencies wanting "to do the right thing" have simply not been shown to create long term viable markets.

California has unique market drivers, such as the AB32 Carbon Reduction Program, that would be expected to create demand for bioproducts. But, rightfully so, the program focuses on major carbon emission sources, such as electric generation, oil refining, natural gas combustion and cement manufacturing. A minor usage, such as a bio-based cleaning product, would either not be covered by the program or must await the development of a protocol for awarding credits, something that may not happen. Near term demand for bioproducts will not likely come from AB32.

When evaluating bioproducts that may assist in creating further demand for the products and by-products created from California's forest management efforts, such by-products may not be the chosen biomass materials for bioproduct manufacturing, even within California. Forest waste, for instance, is higher in moisture content than urban wood or orchard materials. It is also more heterogeneous, consisting of limbs, twigs, tops, bark and needles ground together, and may consist of multiple species. Forest waste is also more disperse and remote from markets than urban or orchard/vineyard sources and thus more costly. Much of the forest waste occurs on public lands, making the consistency of supply more uncertain. The bottom line is that even if bioproducts are developed in California in large quantities despite other hurdles, the use of forest waste as a feedstock will not likely be the first choice.

For the reasons outlined above, BECK developed the screening criteria that were used to rank potential business opportunities utilizing the output of forest management activities. Emerging bioproducts, in general, satisfy virtually none of the screening criteria that were developed, though they may be both innovative and "the right thing to do".

6.1.4.5 Erosion Control

Controlling soil erosion is an objective for many areas containing disturbed soils, including construction sites, roadways, oil and gas drilling, mining operations, burned areas, etc. One of the most common soil erosion prevention measures is to spread agricultural straw across the erodible area. The mulch intercepts rain drops and thereby mitigates the impact of rain hitting and displacing bare soil. The agricultural straw also slows run-off, which decreases the chance for erosion to occur.

Agricultural straw (as well as a mixture of large and small wood chips[26]) has been shown to be effective in controlling erosion. However, with respect to agricultural straw, the drawbacks associated with its use include: it can blow off the site, it decomposes quickly, and it can introduce noxious weeds.

To address these drawbacks to agricultural straw, Forest Concepts, LLC of Auburn, WA developed WoodStraw™. It is manufactured through a relatively simple process in which low grade wood veneer is fed through a machine called a “wood muncher”, which is very similar to a paper shredder. The result is small pieces of wood (with the trade name WoodStraw™) that

[26] Wood Chips as a Soil Cover for Construction Sites with Steep Slopes. American Society of Agricultural and Biological Engineers. Buchanan, et al., 2002. Accessed at: https://elibrary.asabe.org/abstract.asp?aid=11322&t=2&redir=&redirType=

are either 6.3 or 2.5 inches long, 3/16 inch wide and 1/8 to 1/10 inch thick. Fifty percent of the pieces (on a weight basis) are 6.3 inches long and 50 percent are 2.5 inches long. The WoodStraw™ is then spread on areas of bare ground susceptible to erosion. (See **Figure 6.15**)

Figure 6.15 – Woodstraw™ Erosion Control Mulch

Forest Concepts has produced and sold its WoodStraw™ erosion control product from their location in Auburn, but they have also sought to commercialize the enterprise through licensing agreements. To BECK's knowledge, the only existing licensing agreement has been with Mountain Pine Manufacturing, Inc. in Steamboat Springs, Colorado.

At the Auburn facility, Forest Concepts uses fishtail veneer sheets as a raw material. The veneer is purchased from nearby veneer and plywood operations. Historically, this type of veneer can be purchased for about $50 to $75 per ton. Other key costs are labor (2 people), packaging (the material is sold in 50 pound bales, 600 pound bales, or in bulk), and freight cost to deliver the material to end users. A single "wood muncher" machine can produce about 0.9 tons of WoodStraw™ per hour, which is closely matched to a baling machine that can bale about 0.8 tons of WoodStraw™ per hour. Forest Concepts has sought to sell WoodStraw™ at upwards of $300 per ton delivered to the end user.

At Mountain Pine Manufacturing in Steamboat Springs, the "wood muncher" and baler are used just like at the Auburn facility. However, the veneer is produced in a different manner. Mountain Pine Manufacturing's main business is operating a sawmill and its main feedstock is beetle killed lodgepole pine. The sawmill produces 6 inch wide cants of various thicknesses (up to 6 inches). Those cants are then sent to a Baker band resaw machine which can manufacture the cants into dimension lumber or can be set to produce 1/10" thick veneer flitches. Those veneer flitches are then sent to the "wood muncher".

In late 2014, Mountain Pine Manufacturing reported that it had developed a market for its WoodStraw™ among the oil and gas industry where it was being used to provide an initial ground cover on drilling pads. In the open areas of the West, the WoodStraw™ was staying on site in windy conditions. It was also preferred because it did not require water for application like some of the hydromulch products. Other customers of Mountain Pine have included Steamboat Springs Ski Resort, Washington Department of Transportation, Colorado Department of Reclamation and Mine Safety, The Arapahoe Roosevelt National Forest, and Lafarge Spec Ag Quarry. The price that Mountain Pine Manufacturing has been receiving for the WoodStraw™ is not known at this time.

With respect to California, there are likely to be significant markets for erosion control material given the number of wildfires, road construction projects, and other restoration activities taking place each year. However, several significant hurdles exist, including developing the business to a scale where manufacturing costs and product pricing make it competitive with other materials and growing the business large enough scale that it will have an impact across the forest landscape. The Mountain Pine Manufacturing operation recently reported that it consumes about 100 acres worth of beetle killed trees annually, which cannot be considered as an activity that would affect a broad landscape.

In addition, representatives from the U.S. Forest Service Region 5 Burned Area Emergency Recovery team reported that their organization has not been using WoodStraw in large amounts because of its high cost relative to agricultural straw.

6.1.4.6 Excelsior

Excelsior is a product that consists of thin, narrow, ribbon-like strands of wood and has a wide variety of uses. The product is known for its resilience or its ability to expand readily after compression, which makes the product ideal for packaging.

Some additional examples of applications include erosion control blankets, stuffing in taxidermy, use with oil booms, pipeline padding, in archery targets, animal bedding and evaporative cooler pads. Excelsior is made from lower density, softer wood species. The usual species that are utilized in the production of excelsior include cottonwood, aspen, southern yellow pine and basswood.

Wood Excelsior in the packaging industry is an ideal product to use to protect and cushion larger, heavier, or more irregularly shaped products. Excelsior was used to package furniture in the 1950s. The benefits of Excelsior when used in shipping, is that, unlike substitute materials such as packing peanuts, excelsior is an all-natural product that is biodegradable.

Excelsior has been manufactured for over a century, meaning that there is little innovation in the process. There are few companies around that are still producing excelsior, and the ones that are still in business have been doing it for a long time. There are many substitute products for excelsior, meaning the market potential is lower for this product.

6.1.4.7 Extractives

Wood extractives are non-cell wall components that can be removed using solvents such as acetone, pet. ether, ethanol or through steam extraction. Extractives are relatively small molecules that comprise 1-5 percent of the wood. The amount of extractives in the wood is variable depending on the species.

Terpenes and polyphenols are two extractives that have attracted much interest. Terpenes and polyphenols offer significant practical opportunities when targeted to such sectors as pharmacy and cosmetics because of their unique physic-chemical and biological properties. Terpenes represent a wide group of natural hydrocarbon compounds, with the general structure consisting of a series of repeating molecular structures called Isoprenic Units "IP" or C_5). Terpenes are often associated with a tree's resistance to disease and microbial attack. After an attack from a predator or parasitic organism, the concentration of terpenes increases.

Trees utilize terpenoids because the high concentrations of the extractive play a protective role against pathogens and herbivorous animals. Monoterpenes (C_{10}=2 IP units) along with sesquiterpenes (C_{15}=3 IP units) form the main constituents of essential oils. Essential oils have been used as key components in perfumes and aromas. Essential oils are common extractives of trees and plants and serve a variety of purposes. For this project, essential oils as an end product make the most logical sense. The Oregon Woodland Cooperative produces a variety of essential oils from different tree species native to Oregon. The feedstock can be a byproduct of logging or Christmas tree farming; slash or left over trees or unprocessed trees can be the main feedstock in an operation.

The Oregon Woodland Cooperative sells essential oils in 5 ml volumes and charges $15 dollars a vile. It appears that it would be hard to be economically viable as a large scale operation selling small quantities. An ideal solution would be to enter into an agreement with a company that utilizes essential oils in their process – such as an aroma therapy company or a cosmetic company. The yield of essential oil per unit of feedstock is approximately 1 percent, depending on species. If you were to distill one green ton of material, you could expect the yield of essential oil to be about 20 pounds or approximately 9 liters of essential oil.

The main way that essential oil is extracted is through steam extraction via distillation. A fuel source is needed to heat the water to create steam. The steam volatilizes the essential oil compounds, which are then condensed and returned to liquid form. The oil is hydrophobic and less dense than water, so it is easily separated and collected. According to Mr. Robert Seidel of the Essential Oil Company in Portland, Oregon, no one in the U.S. West is manufacturing essential oils from cedar on a large scale. There is one small operation in Myrtle Point, Oregon called Rose City Archery whose main business is making wooden arrow shafts from cedar. They use steam distillation to create essential oils from the byproducts of their arrow manufacturing. These essential oils are used to create a range of products, including Rose of Cedar, which is made from Port Orford Cedar and is used in aroma therapies, cosmetics, perfumes, soaps, disinfectants, pet grooming, and insect repellents. Their 2013 retail prices for this material are shown in **Table 6.7**.

There are commercial scale essential oil operations in Texas that use Eastern Red Cedar as a feedstock. The values shown in **Table 6.7**, are clearly much higher than the current retail prices for Eastern Red Cedar oil, which are shown in **Table 6.8**. It is also important to note that the reported price at which a producer can sell to a remanufacturer or retail/wholesale distributor is between 2 and 3 dollars per pound.

Table 6.7 – 2013 Retail Prices for Port Orford Essential Oil (Rose City Archery, Myrtle Point, OR)

Size	Price ($/unit of volume)	Price ($/pound)
1 ounce	8.80	142.45
2 ounces	13.50	109.26
4 ounces	22.15	89.64
1/2 pint (8 ounces)	37.50	75.88
1 pint (16 ounces)	61.60	62.32
1 quart (32 ounces)	107.40	54.33
1/2 gallon (64 ounces)	181.45	45.89
1 gallon (128 ounces)	303.50	38.38

Table 6.8 – 2013 Retail & Wholesale Prices for Eastern Red Cedar Essential Oil (Texarome, Inc., Leakey, TX)

Size	Price ($/unit of volume)	Price ($/pound)
1 ounce (retail)	3.50	56.66
2 ounces (retail)	5.00	40.47
16 ounces (retail)	24.47	24.76
32 ounces (retail)	47.12	23.84
3 gallons (wholesale)	346.75	13.87
5 gallons (wholesale)	554.80	13.87
1 Drum (55 gallons) (wholesale)	4074.40	9.26

6.1.4.8 Nanocellulose

Cellulose nanomaterials are nanoscale materials derived from trees and other plants. A very crystalline form of cellulose exists in plant cell walls and can be recovered as nano cellulose materials. There are two types of nano-cellulose being investigated: 1) nano-crystals; and 2) nano-fibrils. The crystals are produced from pulping processes to remove lignin and further treating by acid hydrolysis to remove the amorphous cellulose. The resulting pure crystals are typically 3 to 20 nanometers wide and 50 to 500 nanometers long. The nanofibrils are mainly produced by mechanical processes (with or without chemicals) and are not pure cellulose. They are typically 4 to 50 nanometers wide and longer than 500 nanometers in length.

The promises for applications for nano-materials are numerous, especially in medicine, energy, and engineered materials. Due to their crystalline structure, the nano cellulose materials are lightweight, strong, and stiff and possess photonic and piezoelectric properties. Thus, the potential applications for nano crystals and nano fibrils are vast. Examples include aerogels, oil drilling additives, paints, coatings, adhesives, dement, food additives, lightweight packaging materials, paper, health care products, tissue scaffolding, lightweight vehicle armor, space technology, and automotive parts. Indications from many countries are that once nano-materials are produced on a large scale and economically, they will have tremendous applications.

Research and development efforts on nanocellulose have progressed rapidly. However, the focus has been on using bleached pulp as the feedstock. Additional chemistry and engineering processes are necessary as related to whole wood, with bark, and with additional materials that are mixed from forest fuels treatment operations. Trials are underway to find solutions to these issues.

The current cost of production at pilot plant facilities is $12 to $15 per pound. The prevailing knowledge is that the cost needs to be more in the $3 per pound range to be competitive with other materials and allow for commercialization. Some pilot scale operations/research efforts include:

- Domtar/FP Innovations – CelluForce
- Dupont – Biopole
- Southworth
- Schlumberger
- American Process
- P3 Nano – U.S. Endowment and US FPL planning to develop a business case and engineering study (per website)

In addition, the U.S. Forest Service started a wood-based nanotechnology research program at the Forest Products Lab in Madison, Wisconsin in 2006. In 2007, the Forest Service joined the U.S. National Nanotechnology Initiative (NNI) – a collaboration of 26 federal departments and agencies. It soon became apparent that research progress was being hindered by lack of repeatable quantities of wood-derived nano cellulose materials. In 2010, the Forest Service provided funding to construct facilities at the FPL to provide working quantities of Cellulose Nano Crystals. In 2011, the Forest Service provided additional funding for facilities at the University of Maine to produce working quantities of Cellulose Nano Fibrils. Both facilities are currently producing nanocellulose to further both their own research efforts and the efforts of other groups.

A number of challenges remain before investment decisions can be made on commercialization of nano cellulose. Some are:

1. Sufficient engineering data on production of CNC and CNF from woody materials
2. Engineering plans to aid investment decisions such as sites, costs, and throughputs
3. Further market development as more nano cellulose materials become available

While there may be significant indications that nanocellulose has important applications already, the challenges need to be sufficiently overcome before commercialization. Therefore, BECK has concluded that the technology is not appropriate for detailed feasibility analysis and business planning for the CAWBIOM project.

6.1.4.9 Scrimber – Structural and Flooring

Scrimber is a product that utilizes small diameter logs to produce structural quality timber. The process involves separating the wood into interconnected strands, then reforming it into beams using a water-resistant adhesive. The technology was originally developed in Australia as a result of research by the commonwealth Scientific and Industrial Research Organization (CSIRO) for utilizing radiata pine. The product was developed to open new markets for 7-10 year old plantation trees or thinnings from normal forest management operations.

In the early nineties, a production Scrimber mill opened in Mt. Gambier, South Australia that produced Scrimber from radiata pine. In 1994, Georgia Pacific Corporation entered into an agreement with South Australian Timber Corporation to exclusively license the Scrimber technology. Georgia Pacific planned to offer the product priced competitively with sawn lumber. However, to The Beck Group's knowledge, structural Scrimber has never been commercially produced in the U.S.

The first step of the process involves removing the bark. After the bark is removed, tree stems are crushed in a series of rollers in the "scrimming mill," producing bundles of interconnected and aligned strands that largely maintain the original orientation of the wood fiber. At this point in the process, the strands are dried, coated with adhesive, assembled into desired shapes and put through a hot press. The advantage of this process is that more than 85 percent of the logs are utilize in the finished product compared to 40-50 percent utilization obtained by current milling methods.

The product was developed in Australia as a way to utilize small diameter timbers, and at one point, the technology was licensed by Georgia Pacific with the intent of manufacturing the product in the U.S. For this project, Scrimber is a good fit on paper because of the way it is manufactured and that it utilizes small diameter logs. However, because it has not been commercially proven in the U.S., it was eliminated from further consideration for the purposes of this project.

6.2 APPENDIX 2 – FULL SCREENING MATRIX

Technology	Screen 1	Screen 2	Screen 3	Screen 4	Screen 5	Screen 6	Screen 7	Screen 8	Screen 9	Screen 10	Screen 11	Screen 12	Screen 13	Screen 14	Screen Score	Remarks
CLT	1	1	0	0	1	1	1	n/a	1	n/a	6	2	8	10	32	Secure supply of timber required if CLT plant co-located with new sawmill
Veneer - LVL	1	1	1	1	1	1	1	n/a	1	n/a	6	0	8	8	30	Likely need for added capacity of LVL in future; potential supply constraints if only small diameter timber
Small Biomass CHP	1	1	1	1	1	1	1	n/a	1	n/a	4	1	6	10	29	Offset of fossil fueled heat customer
OSB	1	1	1	0	1	1	1	n/a	1	n/a	10	1	6	4	28	Potential regulatory difficulty; adequate raw material supply?
Veneer - Plywood	1	1	1	1	1	1	1	n/a	1	n/a	6	0	6	8	28	potential supply constraints if only small diameter timber
Animal Bedding	1	1	1	1	1	1	1	n/a	1	n/a	2	0	7	10	27	Scale is small
Post and Pole	1	1	1	1	1	1	1	n/a	1	n/a	2	1	6	10	27	Scale is small
I-joists	1	1	1	1	1	1	1	n/a	1	n/a	2	0	6	10	26	Value added to LVL and/or OSB production, so limited direct impact on ability to treat small diameter
Glulam	1	1	1	1	1	1	1	n/a	1	n/a	2	0	6	10	26	Value added to lumber manufacturing, so limited direct impact on ability to treat small diameter
Decorative Bark	1	1	1	1	1	1	1	n/a	1	n/a	2	0	6	10	26	
Firewood	1	1	1	1	1	1	1	n/a	1	n/a	2	0	6	10	26	
Whole Log Chips for Pulp and Paper	1	1	1	0	1	1	1	n/a	0	n/a	8	0	2	10	26	Likely only viable in the Coast region
Large Scale Sawmill	1	1	1	0	1	1	1	n/a	1	n/a	10	0	6	2	25	Secure supply of timber required; good access to markets in Southern CA
Fuel Bricks/logs	1	1	1	0	1	1	1	n/a	1	n/a	2	0	6	10	25	
Mobile Sawmill	0	1	1	0	1	1	1	n/a	1	n/a	6	1	4	8	25	Less product flexibility than a large scale sawmill; secure timber supply needed
Small Gasification/IC Engine CHP	-1	0	1	1	0	1	1	n/a	0	n/a	4	2	6	10	25	Offset of fossil fueled heat customer
Decorative Chips	1	1	1	1	1	1	1	n/a	1	n/a	0	0	6	10	24	
Small Biomass Power	1	1	1	1	1	1	1	n/a	1	n/a	2	1	2	10	23	This evaluation for 3MW & smaller only
Wood Plastic Composite	1	1	1	1	1	1	1	n/a	1	n/a	2	1	2	10	23	
Erosion Control	1	1	1	1	1	1	1	n/a	1	n/a	0	1	4	10	23	
Large Scale Biomass Power	1	1	1	1	1	0	1	n/a	1	n/a	6	0	0	10	23	Evaluated w/o carbon capture/sequestration
Small Scale Sawmill	1	1	1	0	1	1	1	n/a	1	n/a	0	0	6	10	23	
Small Gasification/IC Engine	-1	0	1	1	0	1	1	n/a	0	n/a	2	2	6	10	23	Possible byproduct of biochar
Finger-jointed Lumber	1	1	1	1	1	1	1	n/a	1	n/a	2	0	2	10	22	Value added to lumber manufacturing, so limited direct impact on ability to treat small diameter
Extractives	1	1	1	1	1	1	0	n/a	1	n/a	2	1	4	8	22	Possible added value for slash or mill residues; potential regulatory due to chemicals
Fencing	1	1	1	1	1	1	1	n/a	1	n/a	6	0	6	2	22	Limited supply of cedar in Inland Region
Compost/Mulch	1	1	1	1	1	1	1	n/a	1	n/a	2	0	2	10	22	

Technology	Screen 1	Screen 2	Screen 3	Screen 4	Screen 5	Screen 6	Screen 7	Screen 8	Screen 9	Screen 10	Screen 11	Screen 12	Screen 13	Screen 14	Screen Score	Remarks
Hardboard	1	1	-1	1	1	1	1	n/a	1	n/a	4	0	4	8	22	Secondary supply from mill residuals; potential permitting difficulty?
Parallam	1	1	-1	1	1	1	1	n/a	1	n/a	4	0	4	8	22	Only 1 current manufacturer (Weyerhaeuser)
Excelsior	1	1	1	0	1	1	1	n/a	0	n/a	6	0	0	10	22	
Shingles	1	1	1	0	1	1	1	n/a	1	n/a	0	0	4	10	21	
Nano-Cellulose	-1	-1	0	0	-1	0	1	n/a	-1	n/a	6	2	6	10	21	
Air filtration media	1	1	0	0	0	1	1	n/a	1	n/a	2	1	2	10	20	
Cellulosic Ethanol	-1	-1	1	-1	-1	-1	1	n/a	1	n/a	6	2	4	10	20	
Particleboard	1	1	1	0	1	1	-1	n/a	1	n/a	4	0	2	8	19	Not enough feedstock (mill residues) available
MDF	1	1	1	0	1	1	-1	n/a	1	n/a	4	0	2	8	19	Not enough feedstock (mill residues) available
Pulp and Paper	1	1	1	0	1	1	-1	n/a	1	n/a	6	0	6	2	19	Difficult regulatory environment
Wood Pellets	1	1	1	0	1	1	1	n/a	1	n/a	4	0	4	2	17	Is there adequate market in Japan/China? Lack of Port Infrastructure
Charcoal	1	1	1	0	1	0	0	n/a	1	n/a	2	0	0	10	17	Market moving in wrong direction
Activated carbon	1	1	1	0	1	0	1	n/a	1	n/a	0	0	0	10	16	May not meet quality spec's
Anaerobic digestion	1	1	1	-1	-1	-1	0	n/a	1	n/a	2	1	2	10	16	Could compliment agricultural residue operation
Biochar	-1	1	-1	0	-1	0	-1	n/a	-1	n/a	0	2	6	10	14	Market too small to project
Liquid filtration media	-1	1	-1	0	-1	0	-1	n/a	-1	n/a	0	2	6	10	14	
Scrimber - structural and flooring	-1	-1	-1	-1	-1	0	0	n/a	0	n/a	0	2	4	10	11	
Pyrolysis	-1	-1	-1	-1	-1	0	-1	n/a	-1	n/a	0	2	10	6	11	Requires sustained high oil prices, refinery modifications
Torrefied Wood Pellets	-1	1	0	-1	-1	0	-1	n/a	-1	n/a	0	2	2	10	10	No proven market

Screen Definitions:

Screen 1 - The Technology proposed must have been demonstrated in a commercial setting, at commercial scale, for at least two years.

Screen 2- The Technology supplier/developer must be able to offer commercial warranties as to performance, environmental compliance and completion, and must be able to bond such warranty through commercial sources.

Screen 3 - No single business/technology, in a single development, should consume more than 5 percent of the total market for which it is competing.

Screen 4 - If the business/technology produces a commodity product that is not sold under a long-term "take or pay" contract, the projected economics of the business/technology must be such that it can be shown to be profitable with the lowest commodity prices in each of the last 5 years.

Screen 5 - The business/technology must be capable of being financed through normal commercial channels, with debt/equity ratios in line with other Technologies of similar risk.

Screen 6 - If the business/technology is receiving, through government mandate, special tax credits allowances, etc., the special circumstances must be shown to be in place for the life of the project debt.

Screen 7 - The business/technology must be of a scale such that it can be shown that a single installation is matched to the output/needs of the average California sawmill for treatment of a single by-product stream (e.g., chips, bark, shavings, sawdust, slash).

Screen 8 - The company must be able to demonstrate that it has the appropriate key human and partnership resources in place to deliver the business as envisioned.

Screen 9 - The business/technology must be able to demonstrate that there is a defined and supportable market segment for the product, with potential demand from multiple customers.

Screen 10 - The business/technology must have a business plan that demonstrates through modeling and prior industry comparables a clear revenue model, realistic and comprehensive cost drivers, and steady state profitability.

Screen 11 - If this technology is implemented or expanded in California, it will have a measurable impact on the ability to carry out small diameter forest management treatments.

Screen 12 - Degree of Innovativeness

Screen 13 – Market Attractiveness

Screen 14 - Market; Raw Material; Infrastructure Constraint Specific to California

Scoring Key:

Screens 1-10: -1 = no, does not meet criteria, 0 = maybe or known, 1 = yes, does meet criteria

Screen 11 – Scoring scale from 0 to 10; where a score of 0 = a business that in a single installation uses less than 10,000 green tons of material per year, 2 = 10,000 to 25,000, 4 = 25,000 to 75,000, 6 = 75,000 to 150,000, 8 = 150,000 to 250,000, and 10 = greater than 250,000

Screen 12 – Scoring scale from 0 to 2 where a score of 0 = not innovative, a score of 1 = some innovative aspect, and a score of 2 = new and innovative

Screen 13 – Scoring scale from 0 to 10 where a score of 0 = not all attractive from a market perspective and 10 = most attractive from a market perspective

Screen 14 – Scoring scale from 0 to 10 where a score of 0 = a potentially fatal flaw constraint and 10 = no apparent fatal flaw constraints

6.3 APPENDIX 3 – CALIFORNIA FOREST STAKEHOLDER WORKSHOP FEEDBACK

The following sections provide the feedback received from the Forest Industry Stakeholder workshop for the technologies not selected for detailed review. The feedback for each technology is organized into three sections: strengths; weaknesses; and unknowns.

6.3.1 Large Scale Biomass

6.3.1.1 Strengths

- Lots of feedstock, helps upstream resource
- Qualified renewable resource
- Carbon neutral/proven
- Local power/Local jobs
- Large consumer of low grade fiber – Creates markets for low grade fiber
- Bridge to future technologies
- Has an economy of scale / Cost advantage over small scale biomass
- Supply chain infrastructure is already in place
- Carbon negative – Needs AB32 protocol

6.3.1.2 Weaknesses

- Policies have weaknesses, e.g., focus on low cost – Need adjustment/refinement to portfolio approach
- Who pays – Cost shifting/Cost sharing
  - Air quality, etc. – not monetized
- Existing plants – many not CHP
- Capex required bringing up to date
- Plant level efficiency
- Public perception of Large scale biomass
- Total Cost

6.3.1.3 Unknowns

- A bill is happening now that will set the future viability (AB590) – State of California pick up fair share
- AB32 protocol – impact on facility life
- Greenhouse gas – Justification? Needs rule-making process
- Cap and Trade – 1,000 lbs. $CO2_e$/Bone Dry Ton

- Will Governor Jerry Brown step in and save "industry?"
- At what point does economic life go away?

6.3.2 Post and Pole

6.3.2.1 Strengths

- California is largest market (Agriculture) – Biggest wholesalers of posts and poles in California
- Low capital investment required to start operations
- Posts and poles are more accepting of alternative species
- Posts and poles are a high percentage of imports today
- Efficient supply chain – Infrastructure and known market process
- Underutilized raw material
- Continuous market (e.g., Utility Poles)
- No heat or treatment required – however both can be treated if needed

6.3.2.2 Weaknesses

- Cost increase – by species
- Size overlap/small diameter market
- Some markets very sensitive to specifications – e.g., utility poles
- Modest use of wood to meet capacity of production

6.3.2.3 Unknowns

- Federal contracting requirements
- Is there a market for redwood poles?
- California Forestry rules and regulations
- Small business opportunities?

6.3.3 Animal Bedding

6.3.3.1 Strengths

- Low capital investment required to start operations (estimated at $10 million)
- Use of byproducts (dust) – All used in other products/operations

6.3.3.2 Weaknesses

- Bark haul

- Low margin
- Flat market
- High energy cost
- Supply access
- Weather can be an issue
- Commodity pricing
- Transportation is a high percent of operating costs

6.3.3.3 Unknowns

- Permitting issues in California due to drying

6.3.4 Landscaping Mulch and Soil Amendment

6.3.4.1 Strengths

- Growing demand for product
- Low capital cost required to start operating
- Diverse market
- Low barrier to entry
- Forest biomass is preferred source
- Multiple product streams
- Sold in bulk or in bag
- Drought drives demand for mulch and soil amendment higher

6.3.4.2 Weaknesses

- Relatively low value product
- No greenhouse gas benefits of other alternatives
- Need room – Pushed out geographically
- Permitting issues

6.3.4.3 Unknowns

- Difficult to get permit
- Hard to quantify market size
- Family-owned business – Unknowns associated with the business/hard to measure

6.3.5 I-joist, Glulam, Finger-jointed Lumber

6.3.5.1 Strengths

- Close to large California market; Lower transportation cost to said market
- Strong engineered product for structural applications
- Proven technologies
- Substitute for steel and concrete
- All products connected to CLT – can grow together/complement each other
- Aesthetically appealing
- Modest capital required to start operation
- Mixed market growth rate; potential for some growth
- Permitting may be less challenging than other technologies

6.3.5.2 Weaknesses

- Indirect connection to timber usage
- Tied to new construction trends
- Lot of competition in marketplace from well established companies

6.3.5.3 Unknowns

- Market demand is unknown and tied closely to housing starts